AD-A145 706 SPILLWAY TAILWATER EROSION AT LITTLE GOOSE DAM SNAKE RIVER WASHINGTON HYD..(U) ARMY ENGINEER DIV NORTH PACIFIC BONNEVILLE OR DIV HYDRAULIC L.. M M KUBO 1/1

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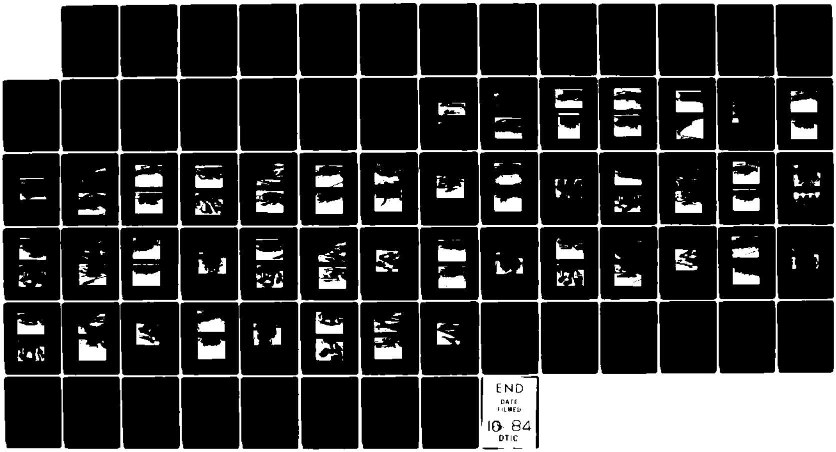

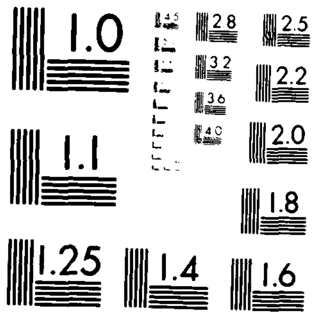

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TECHNICAL REPORT NO. 184-1

HYDRAULIC MODEL
INVESTIGATION

Spillway Tailwater Channel Erosion at Little Goose Dam Snake River, Washington

SPONSORED BY
U. S. ARMY CORPS OF ENGINEERS
WALLA WALLA

CONDUCTED BY
DIVISION HYDRAULIC LABORATORY
U. S. ARMY CORPS OF ENGINEERS
NORTH PACIFIC DIVISION
BONNEVILLE, OREGON

December, 1983

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of Engineers

Unclassified

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Underwater inspection of the Little Goose Dam roller bucket and tailwater channel following about 10 years of operation revealed foundation erosion around various structures and the end of the bucket. A 1:50-scale movable-bed model was used to evaluate the effect of high spillway discharges on the erosional tendencies in the tailwater channel. Studies were accomplished to establish the most desirable spillway operating schedule which would flush the riverbed material and debris from the roller bucket.

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PREFACE

Model studies to investigate erosion tendencies in the tailwater channel downstream of Little Goose Dam spillway were authorized by the U.S. Army Engineer Division, North Pacific (NPD) on 5 March 1979 at the request of U.S. Army Engineer District, Walla Walla (NPW). Studies were conducted at the Division Hydraulic Laboratory, U.S. Army Engineering Division, North Pacific, during the period July 1979 through April 1981.

The model studies were conducted by Mr. T. D. Edmister assisted by Mr. F. S. Bahler under the direct supervision of Mr. R. L. Johnson. Director of the Laboratory was Mr. P. M. Smith. This report was prepared by Mr. M. M. Kubo, Hydraulics Section, U.S. Army Engineer District, Seattle (NPS).

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CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
miles	1.609344	kilometres
feet per second	0.3048	metres per second
cubic feet per second	0.0283168	cubic metres per second
pounds (mass)	0.4535924	kilograms

SPILLWAY TAILWATER CHANNEL EROSION AT LITTLE GOOSE DAM

SNAKE RIVER, WASHINGTON

Hydraulic Model Investigations

PART I: INTRODUCTION

The Prototype

1. Little Goose Dam, a multipurpose project, is located 70.3 river miles upstream from the confluence of the Snake and Columbia Rivers (see figure 1). The salient features of the project include an eight-bay spillway, a six-unit powerhouse, a navigation lock, fish migration facilities, and an excavated tailwater channel. An overall plan of the project is shown on plate 1.

2. The gravity-type spillway (plates 2 and 3) consists of eight 50-foot-wide bays and seven 14-foot-wide piers. Elevation of the spillway crest is 581.0 feet. An 8-foot-long deflector spans the spillway ogee between bays 2 through 7 at elevation 532.0 to reduce the potential for excessive nitrogen supersaturation in the tailwater. The spillway terminates in a dentated, 50-foot-radius roller bucket with an invert elevation of 466.5 feet followed by a 20-foot-long, 20 degree sloping apron. A 40-foot-long gravel apron, beginning immediately downstream from the sloping apron and at an invert elevation of 471.5 feet, intersects the exposed tailwater channel rock at a slope of 1 vertical on 4 horizontal.

Need for Model Study

3. The Little Goose Dam spillway has been in operation for more than 10 years. During recent years, discharges from spillway bays 2 through 7 have been over spillway deflectors that cause skimming flow with discharges under 20,000 cfs per bay. Maximum flow through the

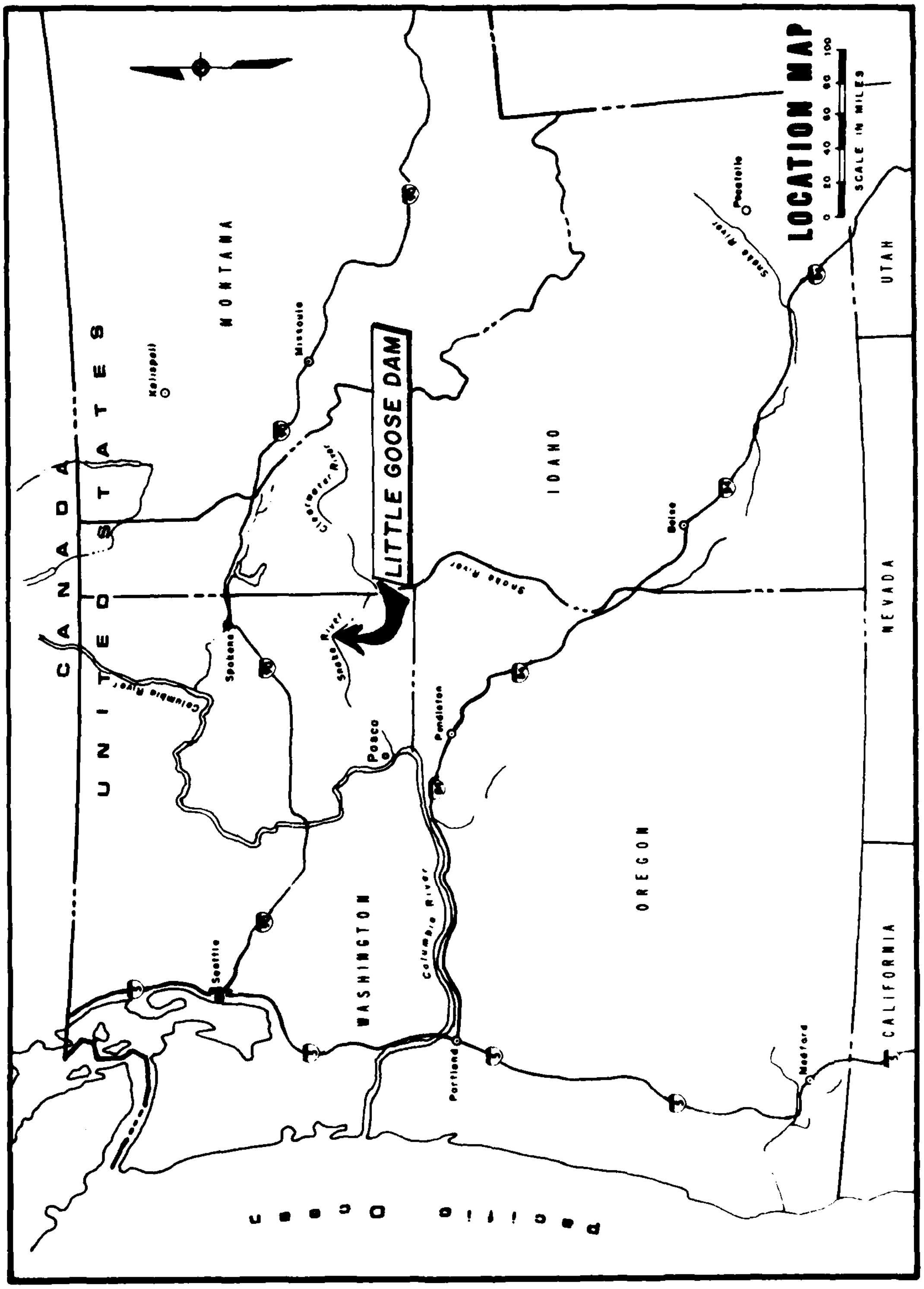
LOCATION MAP
0 20 40 60 80 100
SCALE IN MILES
LITTLE GOOSE DAM
CANADA
UNITED STATES
MONTANA
IDAHO
WASHINGTON
OREGON
NEVADA
UTAH
CALIFORNIA
Pacific Ocean
Columbia River
Snake River
Clearwater River
Kalispell
Missoula
Spokane
Pasco
Pendleton
Boise
Pocatello
Seattle
Portland
Medford

Figure 1

project has been 223,000 cfs, of which 157,000 cfs was over the spillway. Recent hydrographic surveys and diving inspections of the spillway tailwater area have indicated continuing erosion in the area downstream and adjacent to the concrete spillway structure. General erosion of the runout slope has occurred downstream from all spillway bays with a maximum scour of 45 feet at bays 1 through 5. Undercutting has occurred at the downstream edge of the left training wall and the fish dike retaining wall. A model study was considered essential to (1) determine if the erosion would undermine the concrete structures, (2) study erosional patterns and tendencies, (3) establish a spillway operating schedule which would flush the riverbed material and debris from the roller bucket, and (4) study proposals for preventing erosion from endangering the structures.

PART II: THE MODEL

Description

4. The model, constructed to a scale ratio of 1:50, reproduced the entire project area (plate 4). The major structures were constructed of wood, sheet metal, and plastic material. Adjustable spillway tainter gates were used to control the pool elevations. A short forebay was used due to the nature and location of study. Existing forebay channel and overbank features were not reproduced. Tailwater was measured by a piezometer connected to a central gage pit, and an adjustable tailgate was installed to control the tailwater depth. Water was pumped through a recirculating system and measured by means of calibrated orifices in the supply line. Standard laboratory procedures were used to measure water surface elevations, velocities, discharges, etc. The eroded areas were sketched, contoured, and photographed.

5. A movable bed simulating approximately 1,675 feet of spillway tailwater channel and overbank downstream from the spillway crest axis was molded with loosely placed ½-inch minus crushed rock. The loosely placed rock, which simulated loosened pieces of fractured rock existing in the prototype bed, was considered to represent a "conservative condition;" i.e., it would scour more easily than the actual fragmented rock existing in the prototype. The movable bed initially simulated the 10 February 1979 hydrographic survey which included existing eroded areas after 10 years of operation (photographs 1 through 3 and plate 4). The conditions which created the 1979 channel bed configuration (diversion during construction, unbalanced spillway operation, etc.) were generally not documented, therefore no attempt was made at calibrating the bed movement in the model.

Interpretation of Test Results

6. The following accepted equations of hydraulic similitude, based on the Froudian relationship in which gravity is the dominant force, were used to express the mathematical relations between the dimensions and hydraulic quantities of the model and the prototype.

Dimension	Ratio	Scale Relationship
Length	L_r	1:50
Area	$A_r = L_r^{2}$	1:2,500
Velocity	$V_r = L_r^{1/2}$	1:7.071
Time	$T_r = L_r^{1/2}$	1:7.071
Discharge	$Q_r = L_r^{5/2}$	1:17,678

The scour depths depicted in the model should be considered more of a qualitative, rather than quantitative, indicator of erosional tendencies in the prototype because the bed movement in the model was not calibrated. However, because the bed material used in the model was more easily eroded than the prototype bed, the scour depths in the model are considered to be somewhat greater than those which would occur in the prototype. The time required for the erosion shown by the model to occur in the prototype is not duplicated to scale.

PART III: TESTS AND RESULTS

Tailwater Channel Erosion Studies

6. Erosional conditions were observed with 11 river discharges ranging from 120,000 cfs to 530,000 cfs (maximum model capability). With 420,000 cfs (standard project flood) or less, powerhouse units 1 to 3 were in operation. Current project operation spillway gate schedules were used with discharges 200,000 cfs or less while uniform spillway gate operation was used for the larger discharges. The roller bucket was void of debris at the beginning of the tests. Erosion of the tailwater channel was permitted to stabilize with each discharge and after being contoured and photographed was subjected to the next larger flow.

The following photographs and plates show the results of the tests:

River Discharge (cfs)	Spillway Discharge (cfs)	Photographs Flow	Photographs Erosion	Plate Nos.
120,000	55,500	4-5	*	*
160,000	96,600	6-7	8-10	5
200,000	133,000	11-12	13-15	6
250,000	184,000	16-17	18-21	7
280,000	214,000	22-23	24-26	8
300,000	234,000	27-29	30-33	9
350,000	284,000	34-37	38-41	10
400,000	334,000	42-44	45-49	11
420,000	354,000	50-52	53-57	12
475,000	475,000	58-60	61-65	13
530,000	530,000	66-68	69-73	14

*No erosion observed.

8. Flow and erosion conditions observed with each discharge are summarized as follows:

<u>120,000 cfs</u>

Skimming flow from bays 2 to 7. Roller bucket flow from bays 1 and 8. No channel erosion.

<u>160,000 cfs</u>

Flow conditions same as with 120,000 cfs. Approximately 5 feet of erosion at downstream face of bucket at bays 1 and 2, along right training wall, and along fish dike retaining wall. No increase of undercutting of left wall detected.

<u>200,000 cfs</u>

Stronger skimming flow (bays 2 to 7) and roller bucket action (bays 1 and 8). Additional 5 feet of erosion along right wall. Undercutting of fish dike retaining wall extended to full length of wall (bottom of wall at approximately elevation 498 feet). Minor erosion along face of bucket at bays 1 and 2. Rock deposited against face of bucket at bay 4. No rock deposited in the bucket.

<u>250,000 cfs</u>

Skimming flow in bays 2 to 7 more turbulent with standing wave further downstream. Additional 15 feet of erosion along fish dike retaining wall. (Wall not permitted to fail in model. Face of wall extended below erosion.) Fish dike began eroding behind retaining wall. Additional 5 feet of erosion at corner of left wall. Strong bottom roller beneath skimming flow deposited rock against bucket at all bays. Rock deposited in bucket in bays 2 to 6. Some rock constantly moved in the bucket.

280,000 cfs

Flow conditions same as with 250,000 cfs. Additional erosion downstream from bay 7. Additional deposition against bucket at bay 6. No additional erosion at the walls. Rock carried into bucket in bays 4 to 6 and agitated until moved to end bays and washed out of the bucket. Only small amount of rock remained in bucket at end of test.

300,000 cfs

Flow from bays 2 to 5 alternated between skimming and plunging. Surface boils occurred near both training walls. Less rock movement in bucket than with 280,000 cfs. Loose rock and 5 feet of bed material eroded at face of bucket at bay 4. Fish dike erosion increased with material deposited downstream from retaining wall. No additional erosion of hole downstream from left wall or along right wall.

350,000 cfs

Spillway flow predominantly plunging. Rock swept into center bays of bucket, worked to end bays, and washed out. Rock movement less than with smaller flows. Minor additional erosion at bucket in bays 2 to 7 and at fish dike. Some deposition along right wall.

400,000 cfs

Flow plunging in bays 1, 2, 7, and 8 and alternately plunging and skimming in bays 3 to 6. Some rock swept into center of bucket and out at end bays. Additional erosion downstream from retaining wall and from fish dike. Large deposition berm formed 150 feet downstream from retaining wall. Small amount of loose rock deposited along right wall with 350,000 cfs swept downstream. Minor erosion along face of bucket at bays 2 to 8.

420,000 cfs

Flow conditions same as with 400,000 cfs. Minor erosion along and at end of retaining wall. Additional erosion of fish dike. Deposition berm enlarged 200 feet downstream from retaining wall. General erosion 200 feet downstream from bucket at bays 3 to 6.

475,000 cfs

All flow through spillway. Stable plunging flow in all bays. Hole downstream from bay extended downstream 50 feet. Minor additional erosion at downstream end of left wall. Additional 5 feet of erosion 150 feet downstream from bucket at bay 5. About 5 feet of deposition at face of bucket at bays 2 and 3. Additional 15 feet of erosion at end and behind retaining wall. Additional erosion of fish dike. Deposition berm 350 feet downstream from retaining wall.

530,000 cfs

Strong plunging flow and roller bucket action in all bays. Additional 10 feet of erosion at end of retaining wall. Additional erosion of fish dike. Deposition berm shifted downstream to 450 feet from wall. Holes downstream from bays 1, 4, and 5 enlarged but not deepened. Minor deposition at face of bucket at bays 1 to 5.

Bucket Cleanout Studies

9. Analysis of the tailwater channel erosion studies (paragraphs 6 and 7) indicates that the higher discharges caused a large berm of bed material to be deposited approximately 500 feet downstream from the face of roller bucket on the right bank (plates 10 to 14). Backwater effect resulting from the deposited berm was observed, and an attempt was made to develop a spillway gate schedule which would flush the debris from the roller bucket after the floodflow had receded.

10. Observations of potential backwater effect caused by downstream deposition were made with river discharges of 66,000 and 100,000 cfs. During these tests, all flow was passed through the powerhouse utilizing three and six power units, respectively. The deposited material eroded from the spillway channel had negligible effect on the water level at the structures.

11. Five spillway gate operating schedules were tested as bucket cleanout methods. Three power units were operating during each spill. The procedure was to create plunging flow over the deflectors in successive bays to move the loose material to either end of the roller bucket where flow from the bays without deflectors would sweep the material downstream. Gates were opened and closed at a controlled rate to match field conditions. When full plunging flow was obtained in each bay, the material moved out, but as the gates were closed, the flow pattern changed to skimming and gravel moved back in. The maximum discharge per bay in bays 2 to 7 was approximately 43,800 cfs, which was maintained only momentarily while the gate movement was changed from opening to closing. Maximum discharge in the end bays was 10,000 cfs. The operating schedules tested are as follows:

Step	Schedule									
	1		2		3		4		5	
	Gate Operation									
	Open	Close	Open	Close	Open	Close	Open	Close	Open	Close
1	4		1		1		4,5		4,5	
2	3	4	2	1	2		3,6		3,6	4,5
3	2	3	3	2	3	1	2,7	4,5	2,7	3,6
4	1	2	4	3	4	2	1,8	3,6	1,8	2,7
5	5	1	5	4	5	3		2,7		1,8
6	6	5	6	5	6	4		1,8		
7	7	6	7	6	7	5				
8	8	7	8	7	8	6				
9		8		8		7				
10						8				

12. All five spillway gate operating schedules tested were effective in reducing the volume of material in the bucket, but none was successful in flushing the bucket clean. Schedule 5, which used about 6,580 acre-feet of water, was the most effective. Less swirling of gravel occurred under the deflectors during this gate operation than with the other schedules and only a very small amount of rock (70 pieces) remained downstream from bays 4 and 5. A second running of Schedule 5 cleaned out all but a very few pieces of the rock remaining from the first run. Schedules 1 and 3 appeared to be the next most effective. The volume of water used with those two schedules was approximately 8,735 and 19,300 acre-feet, respectively. With Schedules 1 and 3, larger quantities of rock remained between bays 3-6 and bays 2 and 3, respectively.

PART IV: SUMMARY

13. Movable bed studies of the channel downstream from the Little Goose Dam spillway roller bucket were accomplished to evaluate the erosional tendencies in vicinity of the major concrete structures. The movable bed consisted of loosely placed crushed rock which was expected to erode more easily than the fragmented rock which exists in the prototype. The studies indicated that with discharges up to 530,000 cfs (model limit and about 25 percent greater than the standard project flood) undercutting of the left training wall should not significantly increase beyond February 1979 conditions. Only minor undercutting of the wall occurred during the tests. Neither the roller bucket nor the right training wall was undercut; however, a relatively deep hole (about 15 feet in the model) was eroded at the downstream end of the wall. A smaller scour hole was eroded from the face of the bucket at bays 1 and 4. Bed material was generally deposited against the face of the bucket with all flows tested. The fish dike retaining wall was completely undercut to depths of approximately 40 feet. The fish dike behind the wall began to erode with the 200,000-cfs flow (erosion from wave action occurs at lesser discharges in the prototype), and erosion progressed with larger discharges until only about one-third of the dike remained after the 530,000 cfs flow. The eroded material in the model formed a berm 35 feet high directly downstream of the fish dike. With discharges greater than 300,000 cfs, general erosion occurred at all bays throughout a distance about 200 feet downstream from the spillway bucket with the greater erosion occurring at bays 1 and 6 to 8. The material eroded from the spillway tailwater channel was deposited farther downstream in the channel but had negligible effect on tailwater elevations at the concrete structures.

14. In the model, material was swept into the bucket of bays 2 through 7 whenever skimming flow occurred with discharges of 250,000 cfs to 400,000 cfs. Prototype observations indicate that debris is deposited

in the bucket at lower discharges. The rock continued to be moved about in the bucket and progressed sideways into the end bays where it was swept back into the channel. An underwater inspection of the prototype accomplished in August 1979 revealed the existence of concrete erosion and exposed reinforcing steel at various locations in the bucket.*

15. Five spillway gate operating schedules were tested in the model to determine whether bucket flushing could be accomplished. None of the schedules tested were completely successful in flushing the bucket clean of rock; however, all schedules did reduce the volume of material initially located in the bucket.

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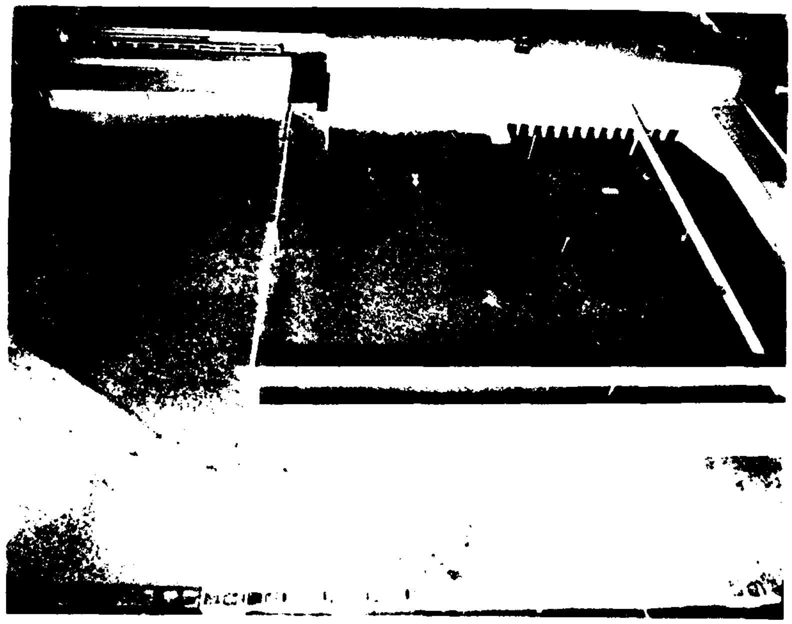
* Little Goose Lock and Dam (Lake Bryan) Snake River, Washington, Inspection Report 7, May 1980, U.S. Army Engineer District, CE, Walla Walla, WA.



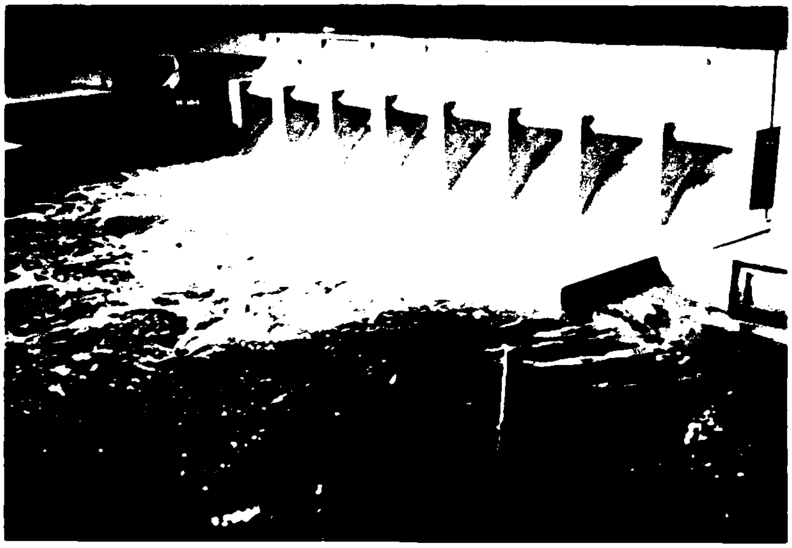
Photograph 1

1:50-scale movable bed model with
downstream channel topography of 10 Feb. 79

Photograph 2

Photograph 3

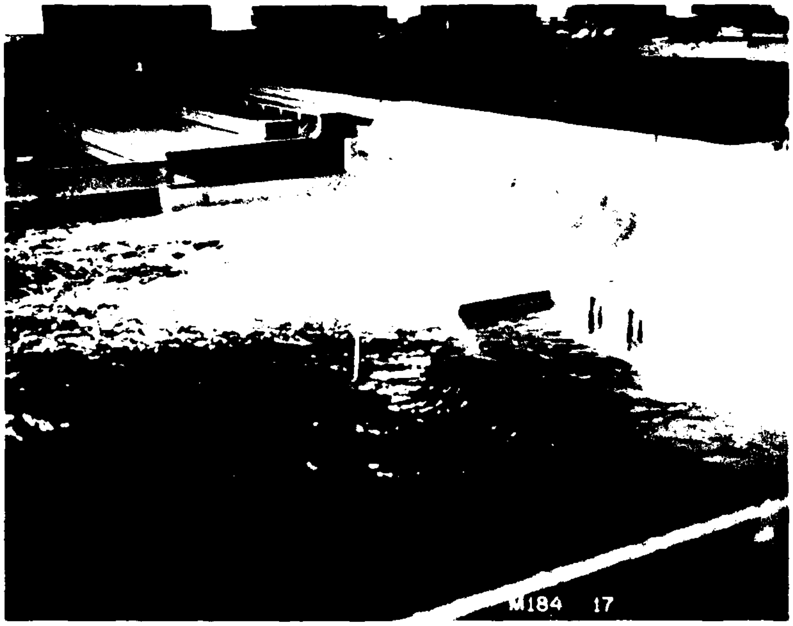
Structure and downstream channel topography of 10 Feb. 79



Photograph 4

Photograph 5

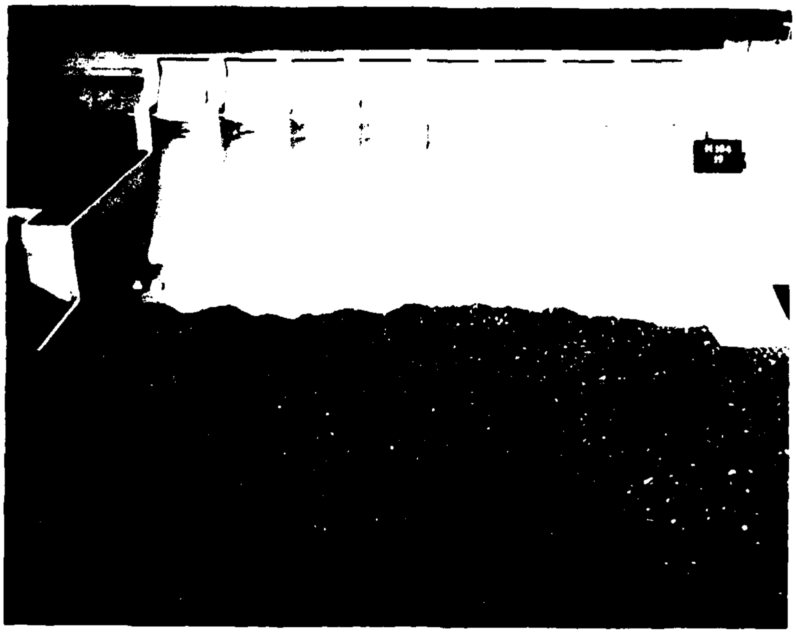
Surface flow conditions at spillway
River discharge 120,000 cfs, tailwater elev. 541.2
Spillway discharge 55,500 cfs, pool elev. 638
Powerhouse units 1 to 3, discharge 64,500 cfs



Photograph 6

Photograph 7

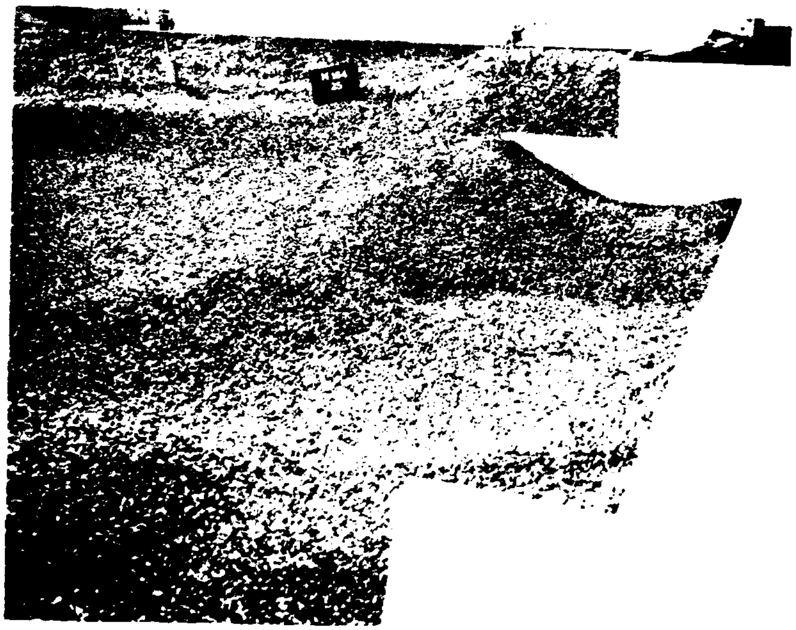
Surface flow conditions at spillway
River discharge 160,000 cfs, tailwater elev. 541.9
Spillway discharge 96,600 cfs, pool elev. 638
Powerhouse units 1 to 3, discharge 63,300 cfs



Photograph 8

Photograph 9

Channel topography after river discharge 160,000 cfs
with spillway discharge 96,600 cfs



Photograph 10

Channel topography after river discharge 160,000 cfs
with spillway discharge 96,600 cfs

Photograph 11

Photograph 12

Surface flow conditions at spillway
River discharge 200,000 cfs, tailwater elev. 542.8
Spillway discharge 133,000 cfs, pool elev. 638
Powerhouse units 1 to 3, discharge 66,900 cfs

Photograph 13

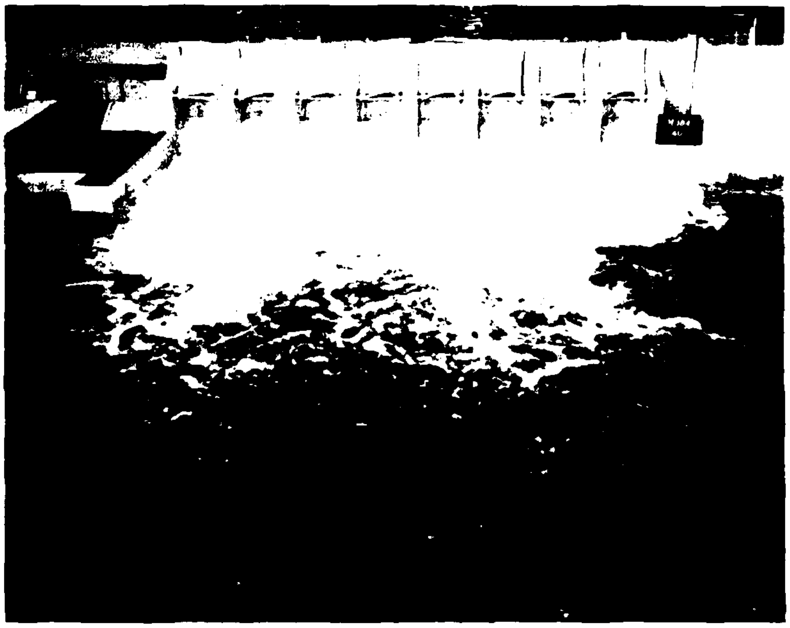
Channel topography after discharge 200,000 cfs
with spillway discharge 133,000 cfs

Photograph 14

Photograph 15

Channel topography after river discharge 200,000 cfs
with spillway discharge 133,000 cfs

Photograph 16



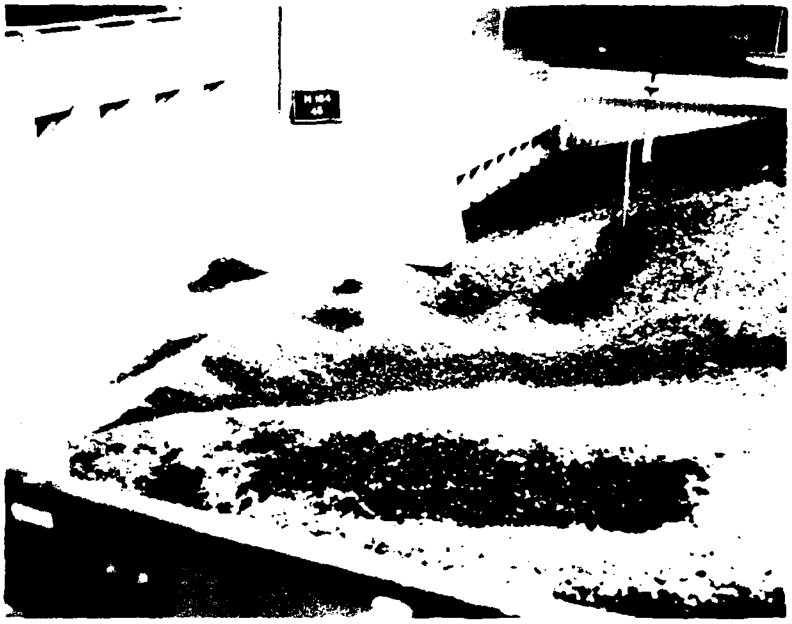
Photograph 17

Surface flow conditions at spillway
River discharge 250,000 cfs, tailwater elev. 544.0
Spillway discharge 184,000 cfs, pool elev. 638
Powerhouse units 1 to 3, discharge 66,000 cfs

Photograph 18

Photograph 19

Channel topography after river discharge 250,000 cfs
with spillway discharge 184,000 cfs



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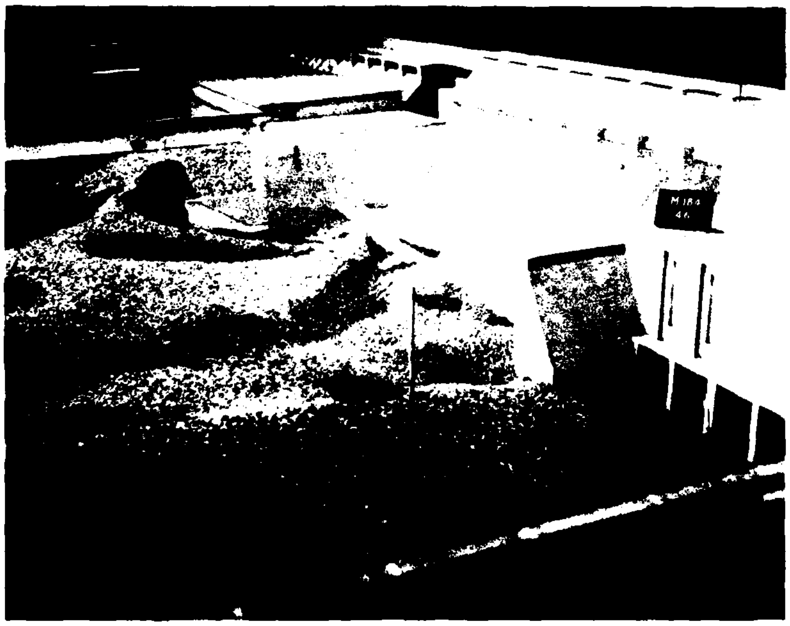
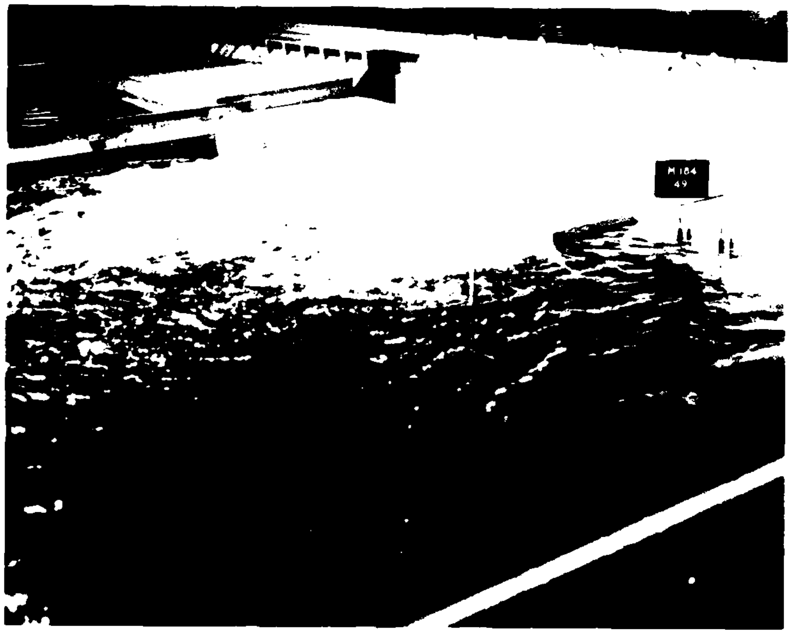


Photograph 21

Channel topography after river discharge 250,000 cfs
with spillway discharge 184,000 cfs



Photograph 22

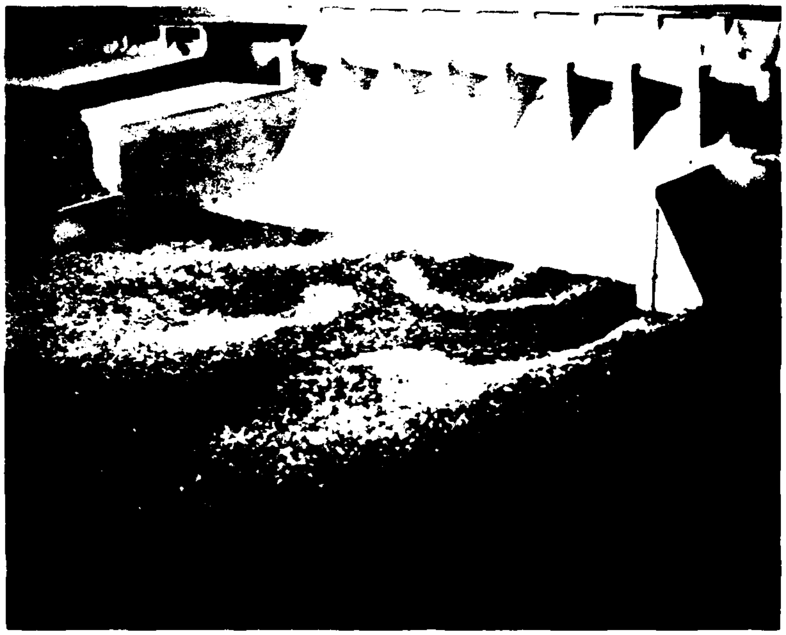
Photograph 23

Surface flow conditions at spillway
River discharge 280,000 cfs, tailwater elev. 544.7
Spillway discharge 214,000 cfs, pool elev. 638
Powerhouse units 1 to 3, discharge 66,000 cfs

Photograph 24

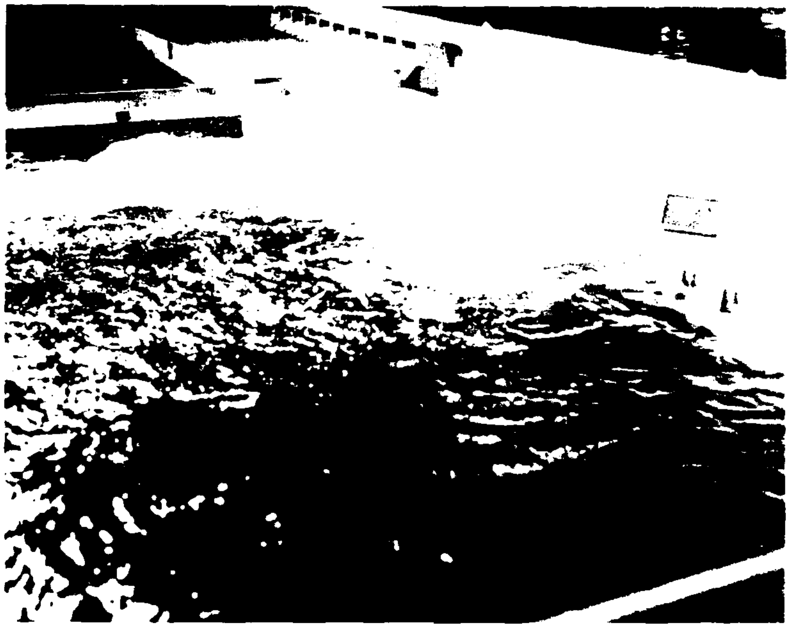
Photograph 25

Channel topography after river discharge 280,000 cfs
with spillway discharge 214,000 cfs

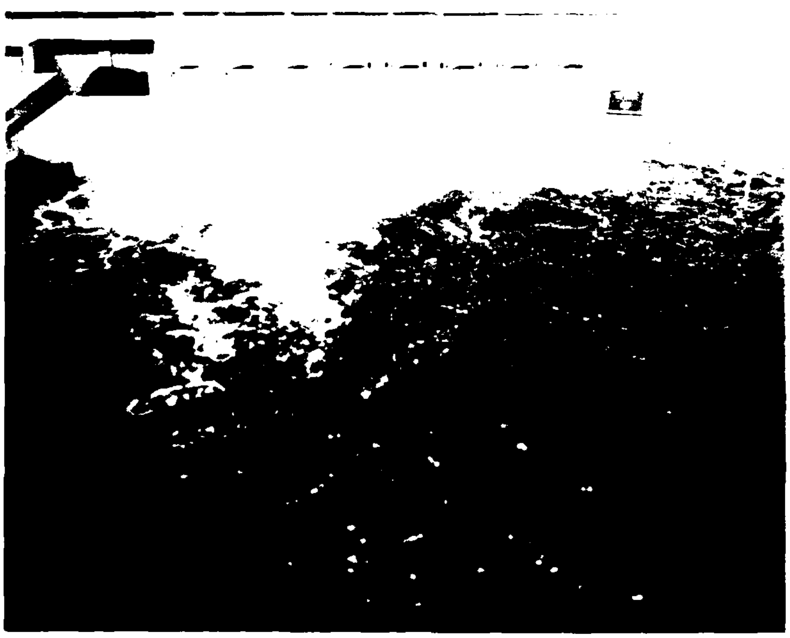


Photograph 26

Channel topography after river discharge 280,000 cfs
with spillway discharge 214,000 cfs



Photograph 27



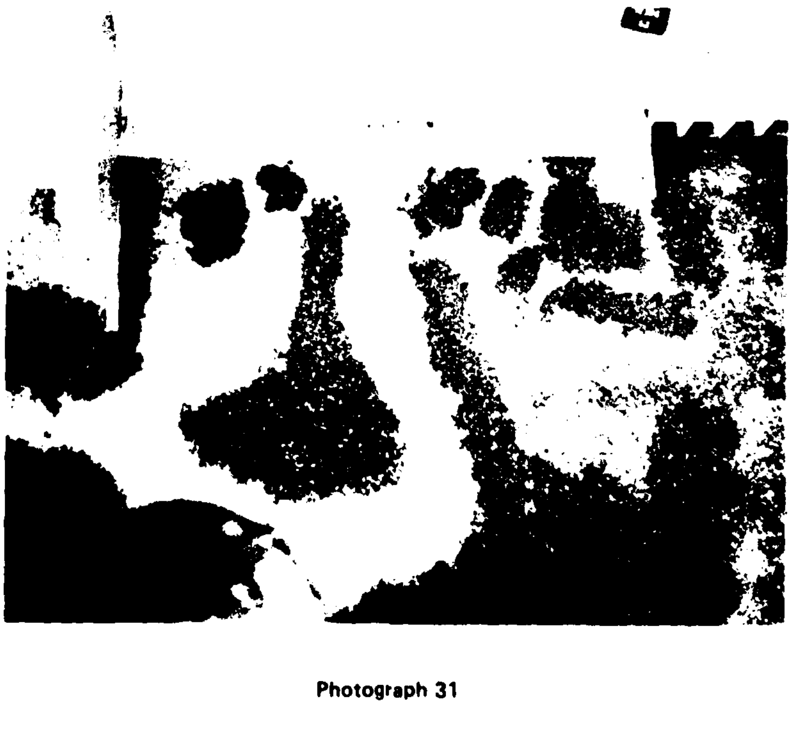
Photograph 28

Surface flow conditions at spillway
River discharge 300,000 cfs, tailwater elev. 545.2
Spillway discharge 234,000 cfs, pool elev. 638
Powerhouse units 1 to 3, discharge 66,000 cfs

Photograph 29

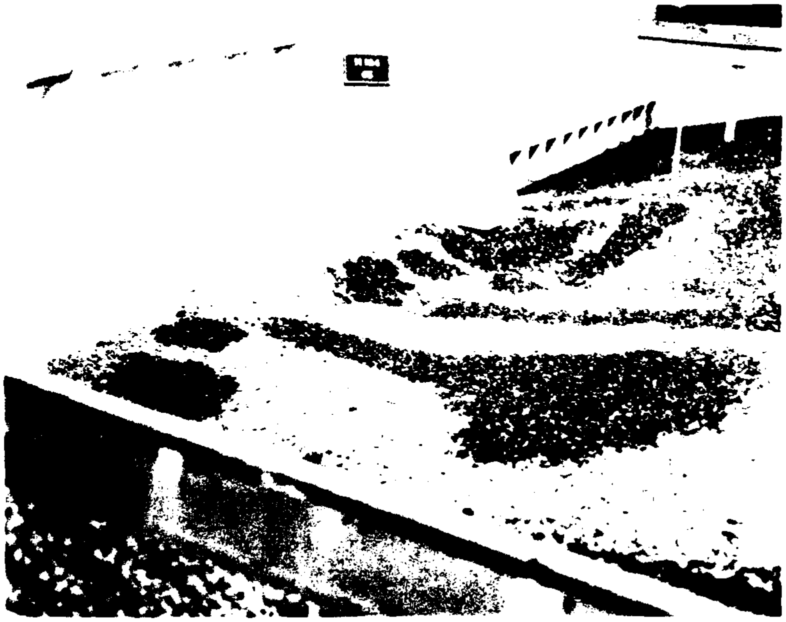
Surface flow conditions at spillway
River discharge 300,000 cfs, tailwater elev. 545.2
Spillway discharge 234,000 cfs, pool elev. 638
Powerhouse units 1 to 3, discharge 66,000 cfs

Photograph 30



Photograph 31

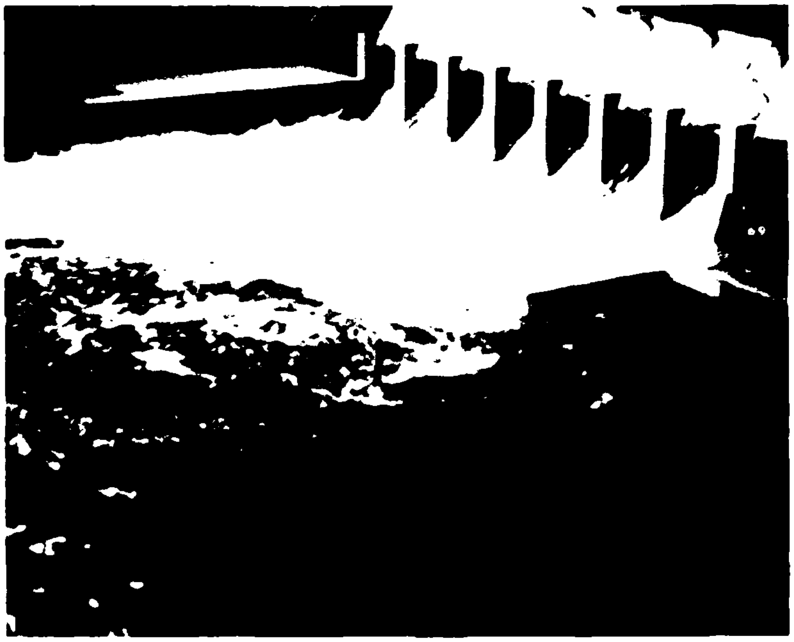
Channel topography after river discharge 300,000 cfs
with spillway discharge 234,000 cfs



Photograph 32

Photograph 33

Channel topography after river discharge 300,000 cfs with spillway discharge 234,000 cfs



Photograph 34

Photograph 35

Surface flow conditions at spillway
River discharge 350,000 cfs, tailwater elev. 546.5
Spillway discharge 284,000 cfs, pool elev. 638
Powerhouse units 1 to 3, discharge 66,000 cfs

Photograph 36

Photograph 37

Surface flow conditions at spillway
River discharge 350,000 cfs, tailwater elev. 546.5
Spillway discharge 284,000 cfs, pool elev. 638
Powerhouse units 1 to 3, discharge 66,000 cfs

Photograph 38

Photograph 39

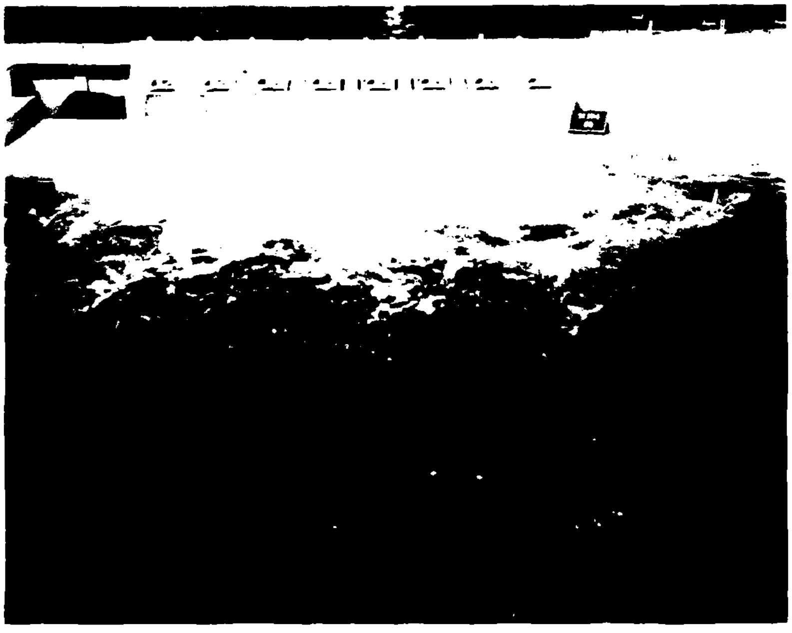
Channel topography after river discharge 350,000 cfs
with spillway discharge 284,000 cfs

Photograph 40

Photograph 41

Channel topography after river discharge 350,000 cfs
with spillway discharge 284,000 cfs

Photograph 42



Photograph 43

Surface flow conditions at spillway
River discharge 400,000 cfs, tailwater elev. 547.8
Spillway discharge 334,000 cfs, pool elev. 638
Powerhouse units 1 to 3, discharge 66,000 cfs

Photograph 44

Surface flow conditions at spillway
River discharge 334,000 cfs, tailwater elev. 547.8
Spillway discharge 334,000 cfs, pool elev. 638
Powerhouse units 1 to 3, discharge 66,000 cfs

Photograph 45

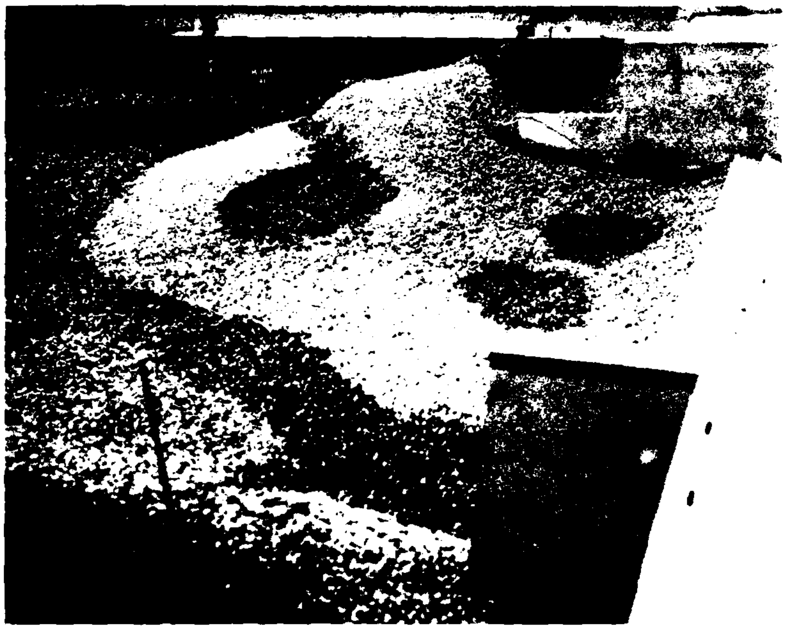
Photograph 46

Channel topography after river discharge 400,000 cfs
with spillway discharge 334,000 cfs

Photograph 47

Photograph 48

Channel topography after river discharge 400.000 cfs
with spillway discharge 334,000 cfs



Photograph 49

Channel topography after river discharge 400,000 cfs
with spillway discharge 334,000 cfs

Photograph 50

Photograph 51

Surface flow conditions at spillway
River discharge 420,000 cfs, tailwater elev. 548.3
Spillway discharge 354,000 cfs, pool elev. 638
Powerhouse units 1 to 3, discharge 66,000 cfs

Photograph 52

Surface flow conditions at spillway
River discharge 420,000 cfs, tailwater elev. 548.3
Spillway discharge 354,000 cfs, pool elev. 638
Powerhouse units 1 to 3, discharge 66,000 cfs

Photograph 53

Photograph 54

Channel topography after river discharge 420,000 cfs with spillway discharge 354,000 cfs

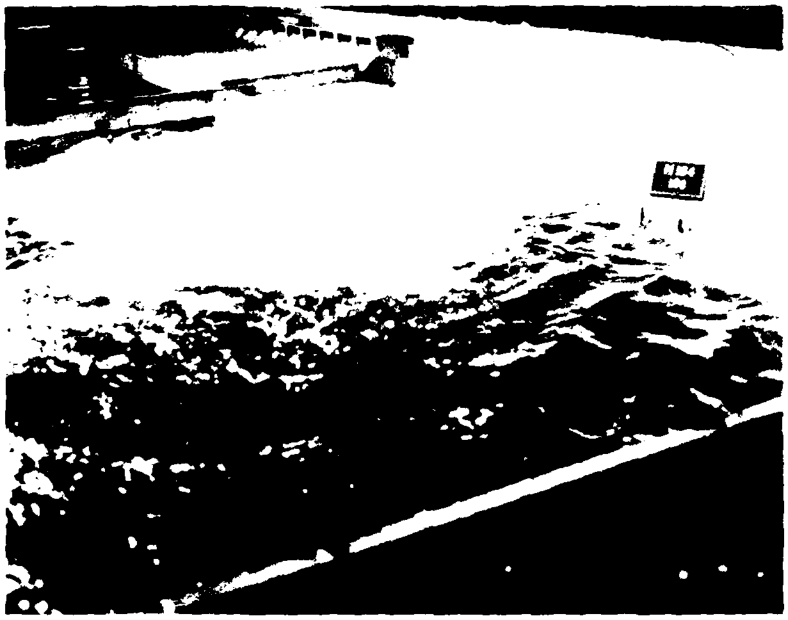
Photograph 55

Photograph 56

Channel topography after river discharge 420,000 cfs with spillway discharge 354,000 cfs

Photograph 57

Channel topography after river discharge 420,000 cfs
with spillway discharge 354,000 cfs



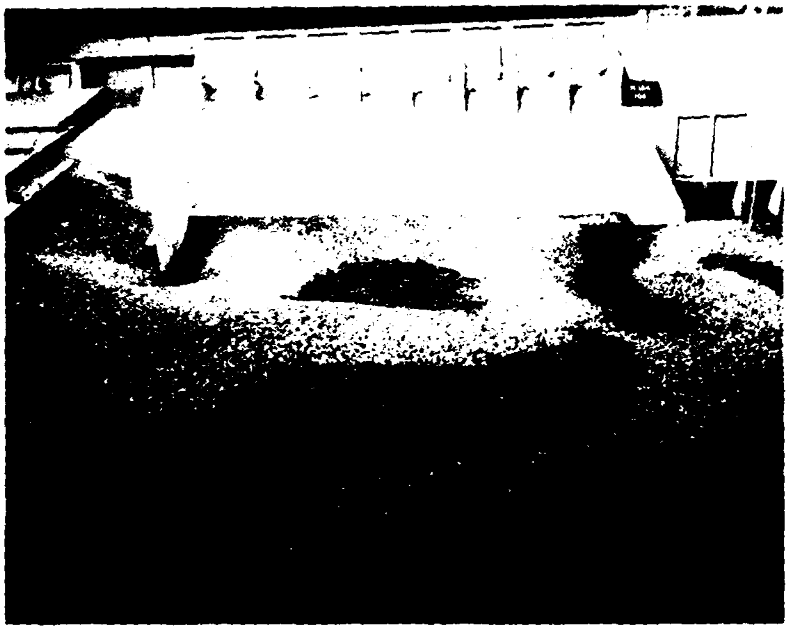
Photograph 58

Photograph 59

Surface flow conditions at spillway
River discharge 475,000 cfs, tailwater elev. 549.5
Spillway flow only, pool elev. 638

Photograph 60

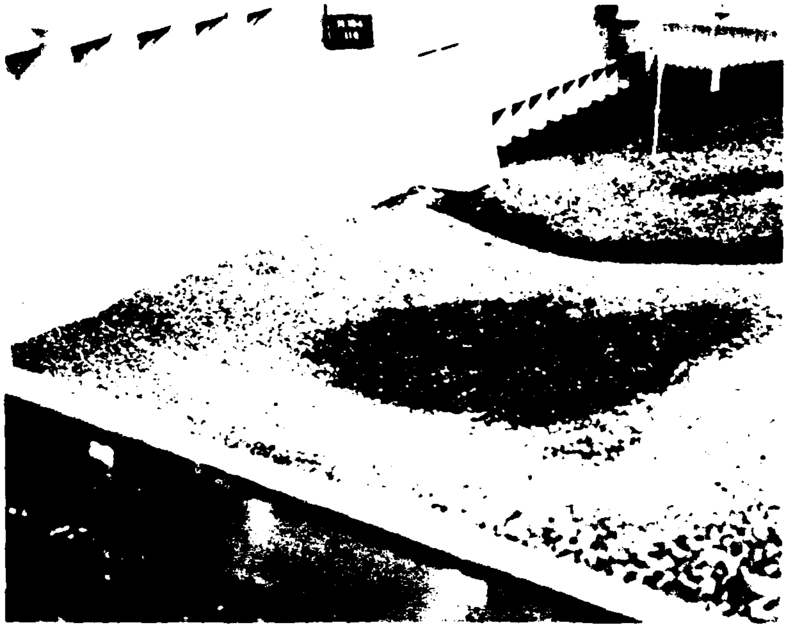
Surface flow conditions at spillway
River discharge 475,000 cfs, tailwater elev. 549.5
Spillway flow only, pool elev. 638



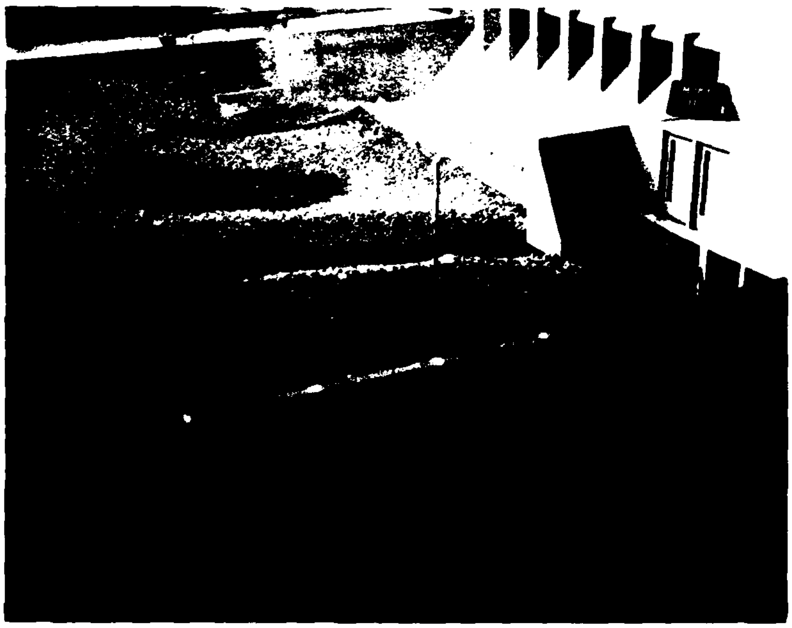
Photograph 61

Photograph 62

Channel topography after river discharge 475,000 cfs
with spillway flow only



Photograph 63

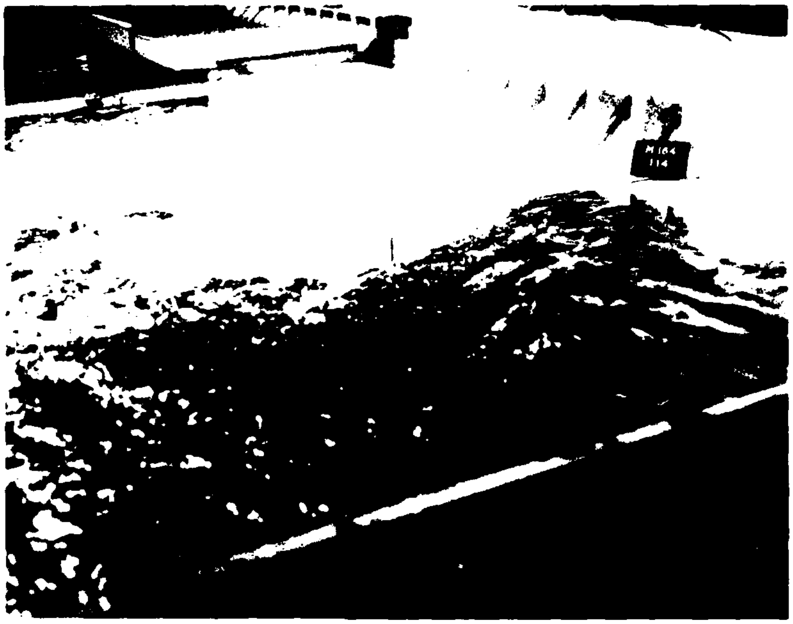


Photograph 64

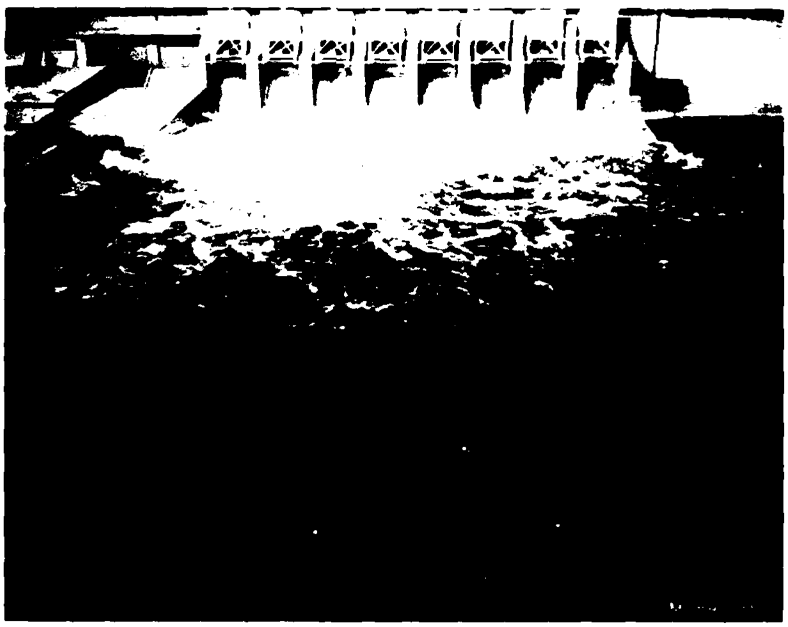
Channel topography after river discharge 475,000 cfs
with spillway flow only

Photograph 65

Channel topography after river discharge 475,000 cfs
with spillway flow only

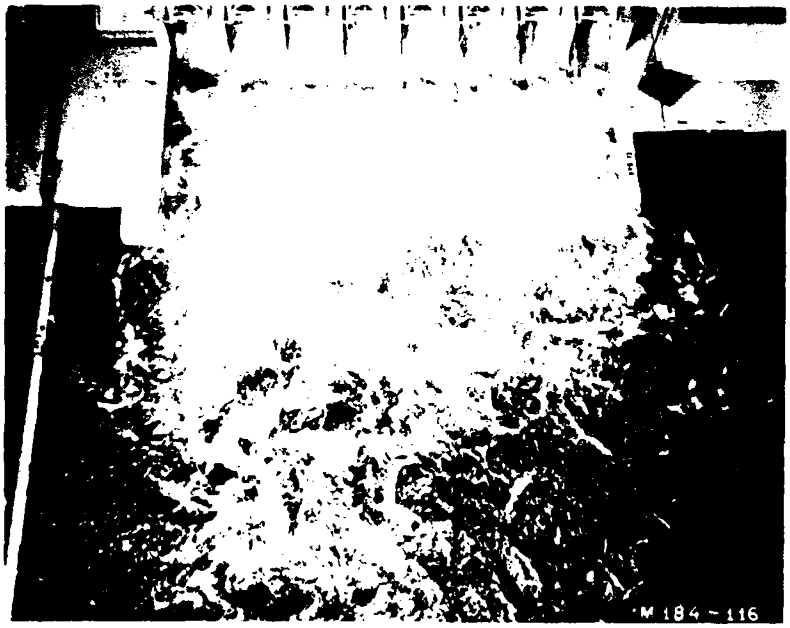


Photograph 66



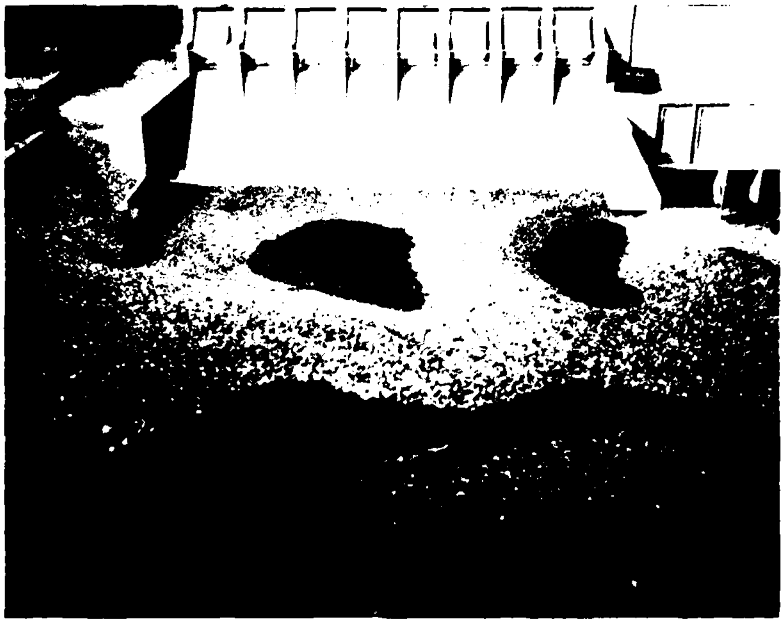
Photograph 67

Surface flow conditions at spillway
River discharge 530,000 cfs, tailwater elev. 551.0
Spillway flow only, pool elev. 638



Photograph 68

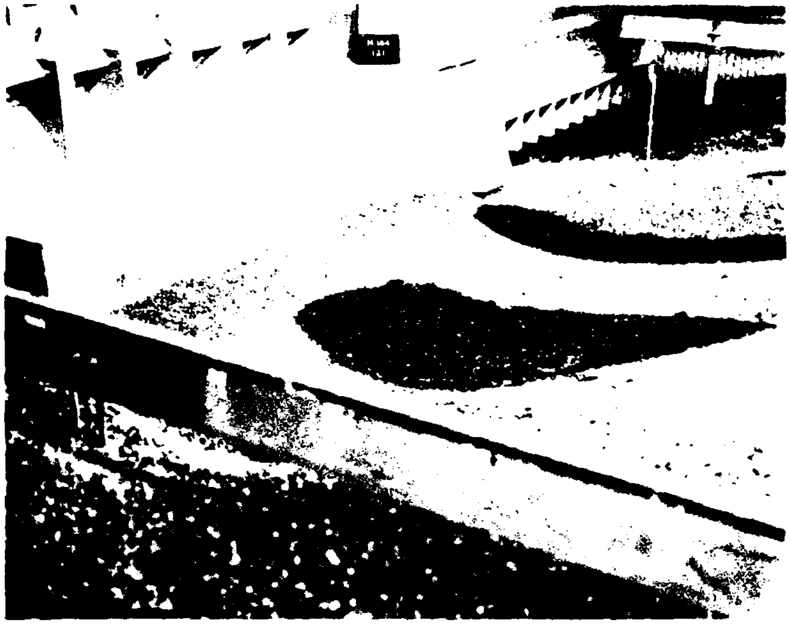
Surface flow conditions at spillway
River discharge 530,000 cfs, tailwater elev. 551.0
Spillway flow only, pool elev. 638



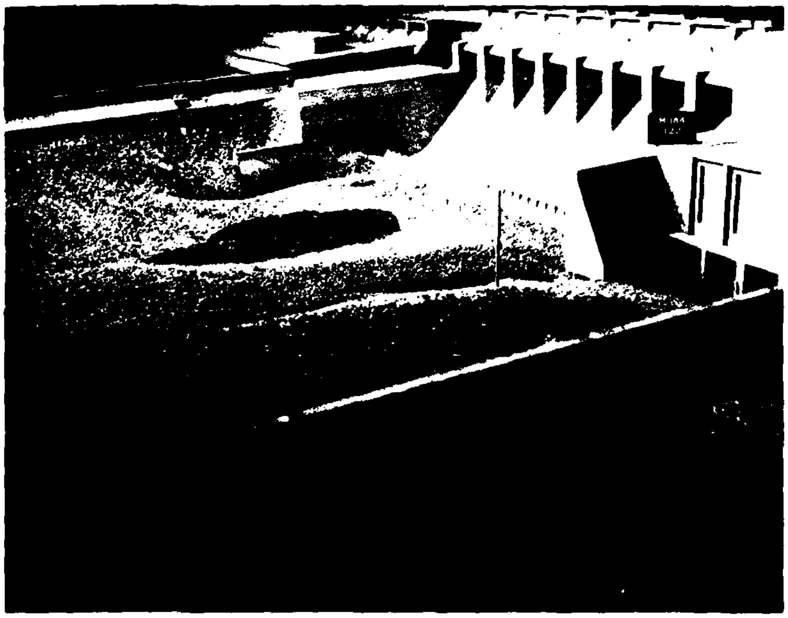
Photograph 69

Photograph 70

Channel topography after river discharge 530,000 cfs
with spillway flow only

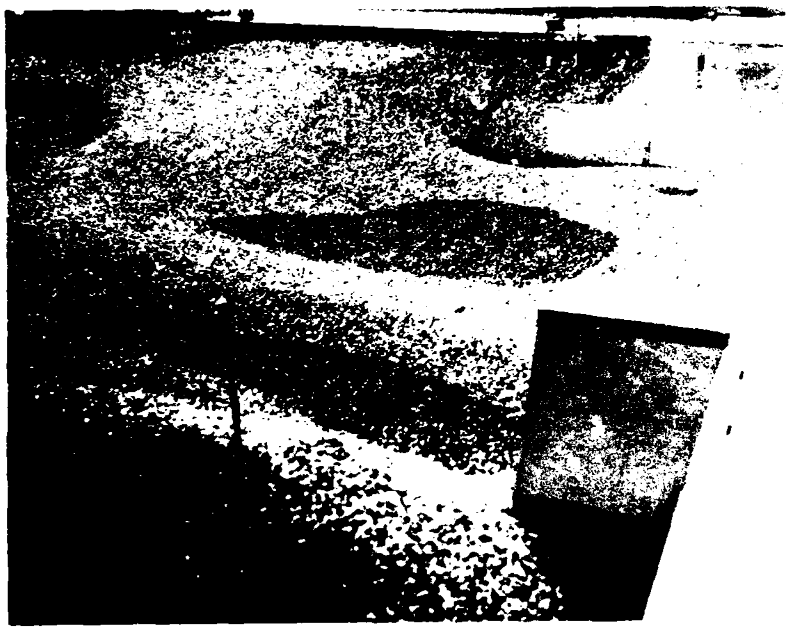


Photograph 71



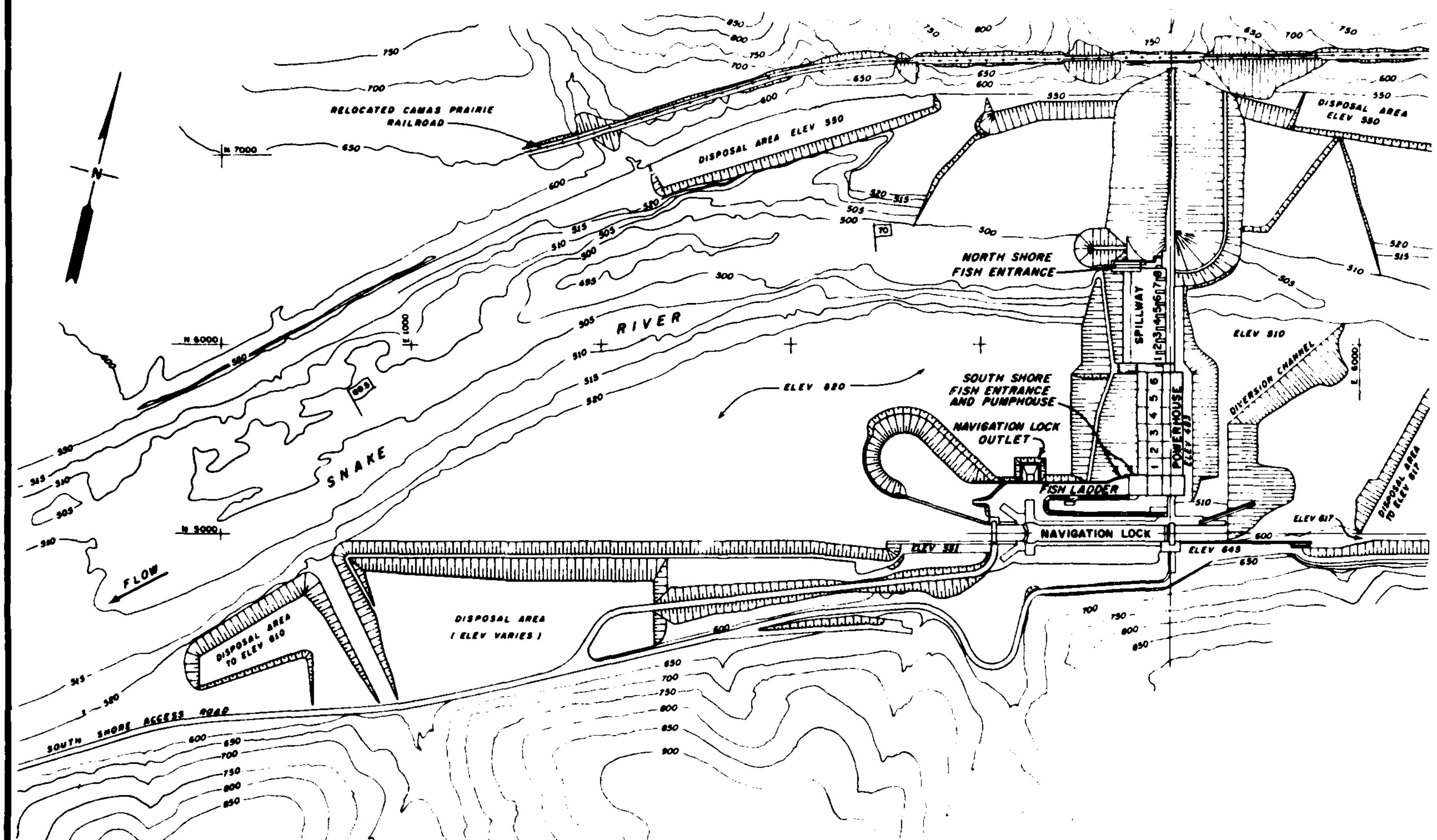
Photograph 72

Channel topography after river discharge 5300,000 cfs
with spillway flow only

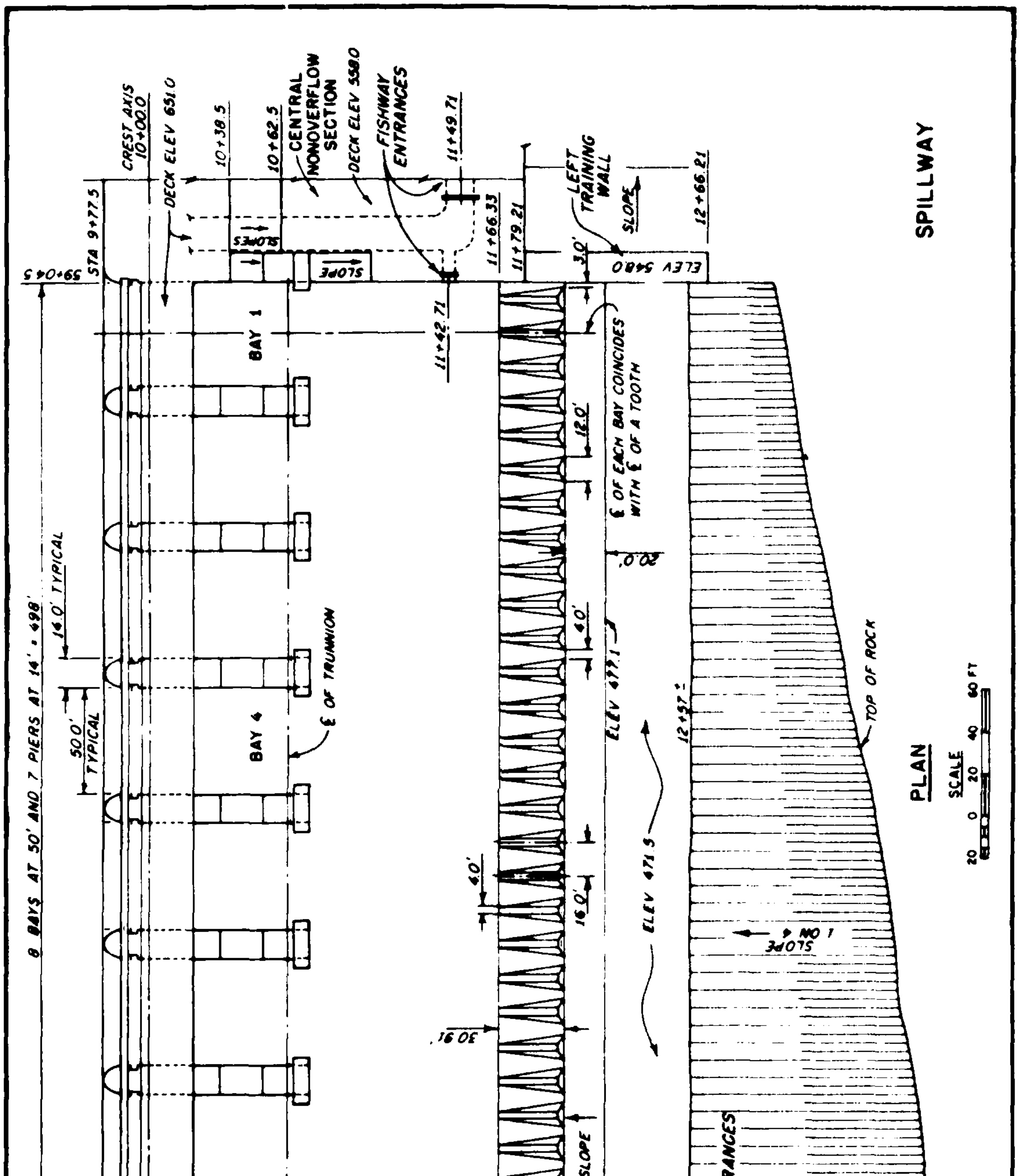


Photograph 73

Channel topography after river discharge 530,000 cfs
with spillway flow only



PROJECT LAYOUT



SPILLWAY
PLAN
SCALE
20 0 20 40 60 FT
CREST AXIS 10+00.0
DECK ELEV 651.0
10+38.5
10+62.5
CENTRAL NONOVERFLOW SECTION
DECK ELEV 558.0
FISHWAY ENTRANCES
11+49.71
LEFT TRAINING WALL
SLOPE
12+66.21
ELEV 548.0
STA 9+77.5
59+04.5
11+66.33
11+79.21
11+42.71
BAY 1
BAY 4
BAY 8
8 BAYS AT 50' AND 7 PIERS AT 14' = 498'
14.0' TYPICAL
50.0' TYPICAL
℄ OF TRUNNION
℄ OF EACH BAY COINCIDES WITH ℄ OF A TOOTH
12.0'
20.0'
4.0'
16.0'
3.0'
30.91'
ELEV 477.1
ELEV 471.5
12+57±
SLOPE 1 ON 4
TOP OF ROCK
FISHWAY ENTRANCES
12+93.17
13+11.17
RETAINING WALL ELEV 508.0
14+01.17
12'±
RIGHT TRAINING WALL ELEV 553.0
℄ FISH CHANNEL, FLOOR ELEV 525.0
BERM ELEV 505.0
SLOPE 1 ON 1.75
STA 64+02.5
NORTH NONOVERFLOW SECTION

PLATE 2

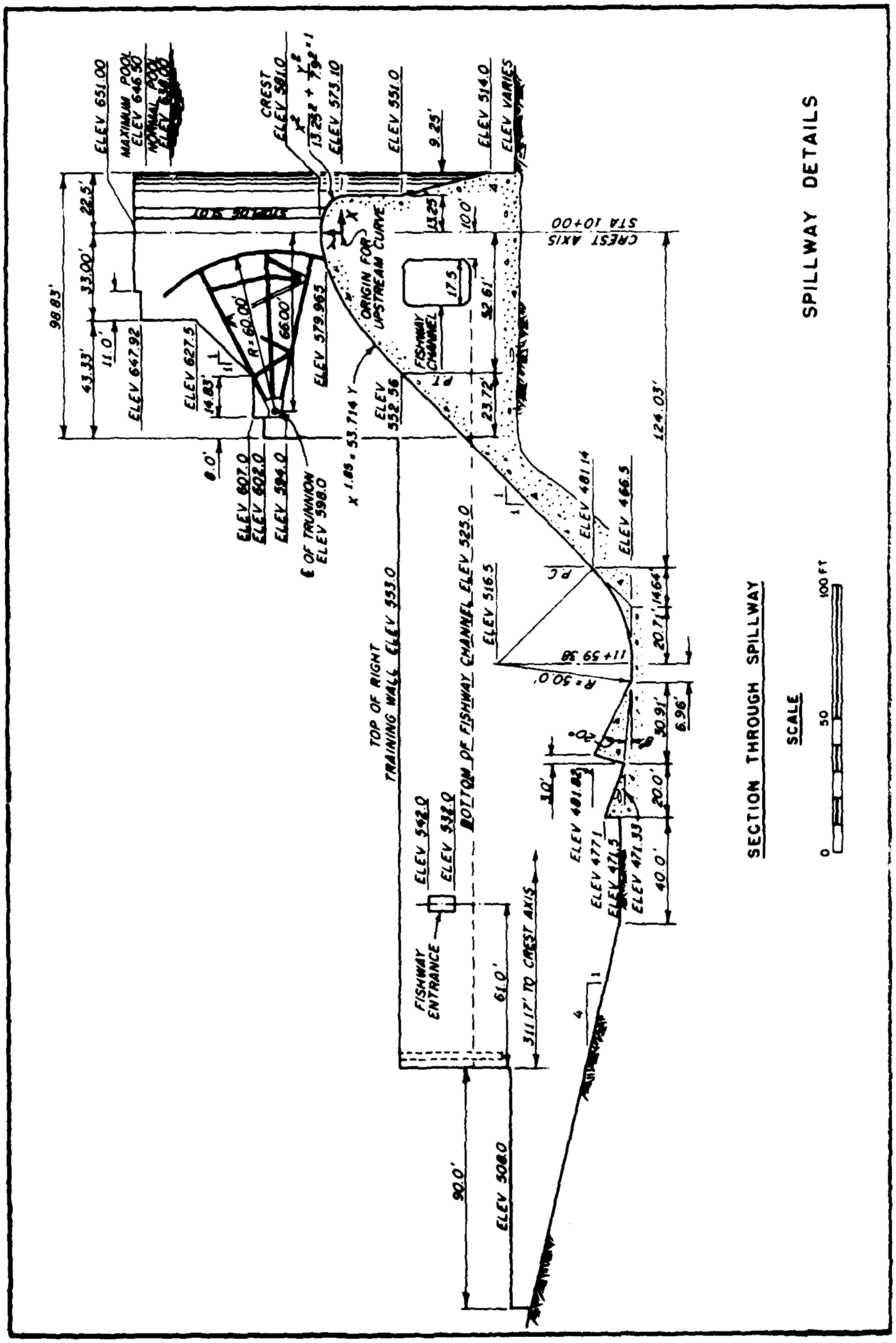
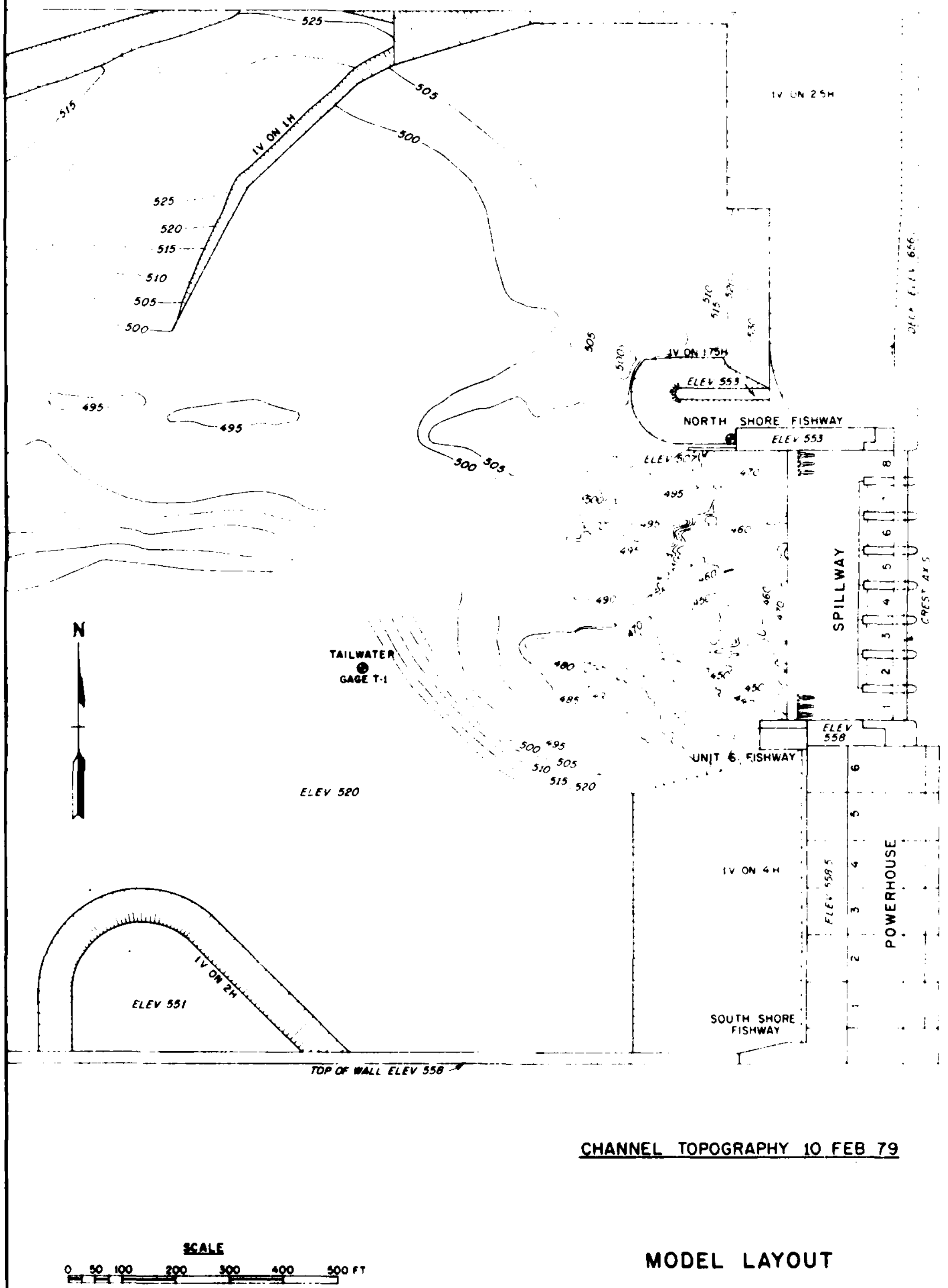

SPILLWAY DETAILS
SECTION THROUGH SPILLWAY
SCALE
0
50
100 FT
ELEV 651.00
MAXIMUM POOL ELEV 646.50
CREST ELEV 581.0
ELEV 573.10
ELEV 551.0
ELEV 514.0
ELEV VARIES
STA 10+00
CREST AXIS
ORIGIN FOR UPSTREAM CURVE
FISHWAY CHANNEL
ELEV 579.965
ELEV 627.5
ELEV 647.92
ELEV 607.0
ELEV 602.0
ELEV 584.0
℄ OF TRUNNION ELEV 598.0
R=60.00'
66.00'
98.83'
43.33'
33.00'
22.5'
11.0'
14.83'
8.0'
9.25'
13.25
10.0'
17.5
52.61'
23.72'
124.03'
P.T.
P.C.
ELEV 552.56
$X^{1.85} = 53.714\ Y$
ELEV 481.14
ELEV 466.5
ELEV 516.5
R=50.0'
11+59.38
20.71'
14.64
30.91'
6.96'
20.0'
40.0'
3.0'
ELEV 481.82
ELEV 477.1
ELEV 471.5
ELEV 471.33
TOP OF RIGHT TRAINING WALL ELEV 553.0
BOTTOM OF FISHWAY CHANNEL ELEV 525.0
ELEV 542.0
ELEV 532.0
FISHWAY ENTRANCE
61.0'
311.17' TO CREST AXIS
90.0'
ELEV 508.0
4
1

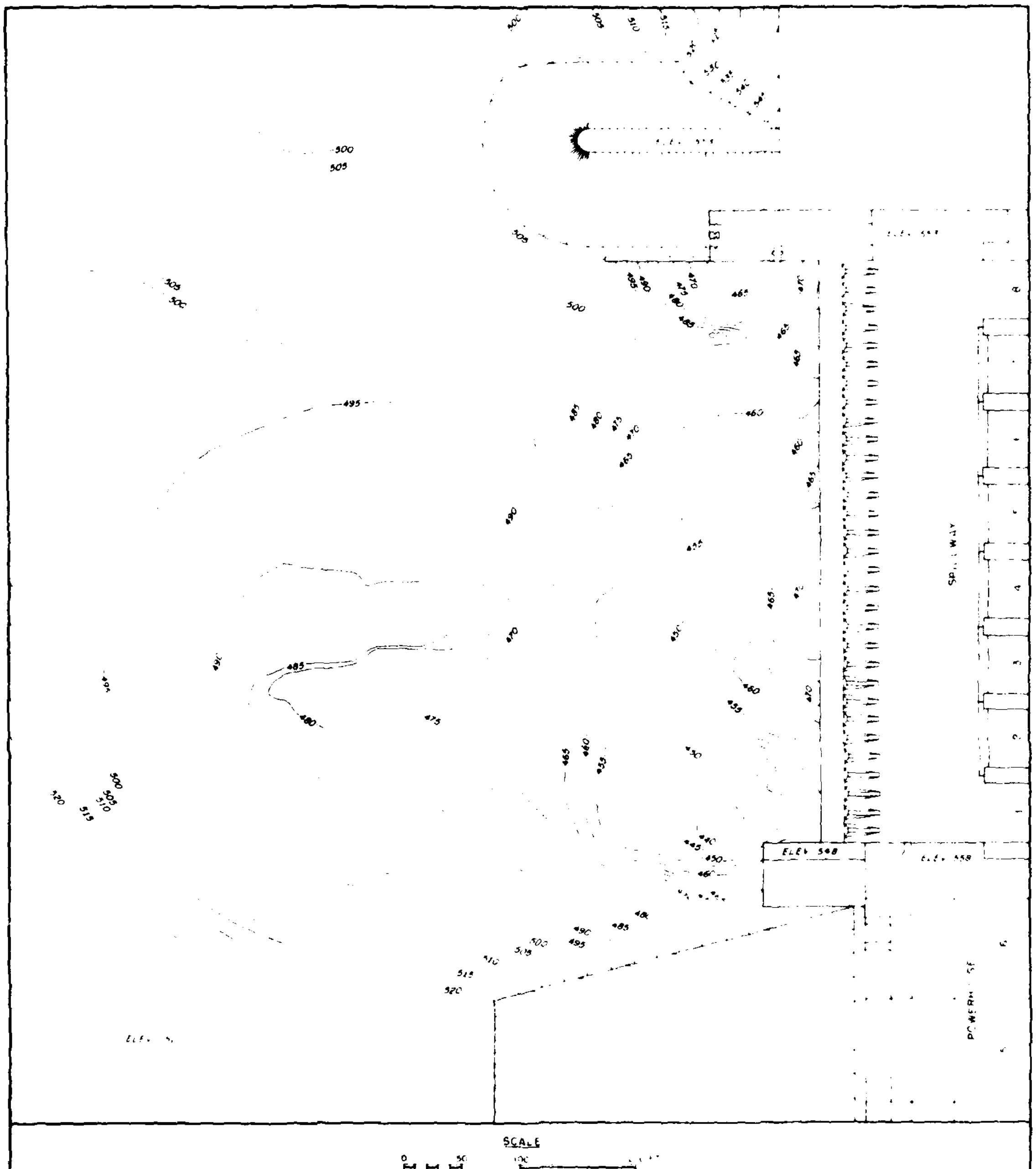
PLATE 3



CHANNEL TOPOGRAPHY 10 FEB 79

MODEL LAYOUT

PLATE 4

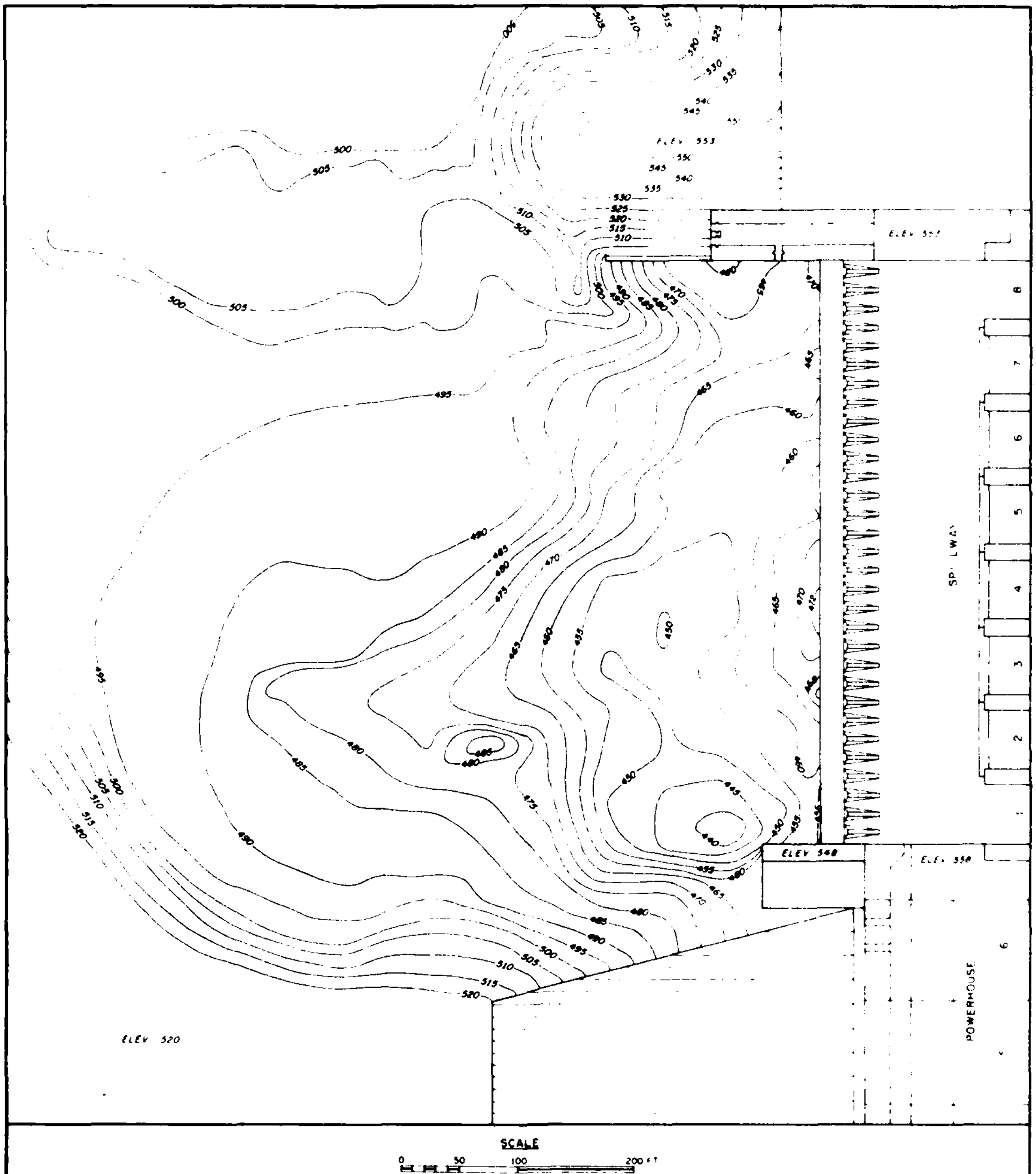


OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 3	63 300 CFS
SPILLWAY	
BAYS 1 AND 8	28 200 CFS
BAYS 2, 4, 5, AND 7	48 500 CFS
BAYS 3 AND 6	20 000 CFS
POOL ELEVATION	638.0
TAILWATER ELEVATION	541.9
TEST DURATION	21 HOURS

CHANNEL TOPOGRAPHY

RIVER DISCHARGE 160 000 CFS



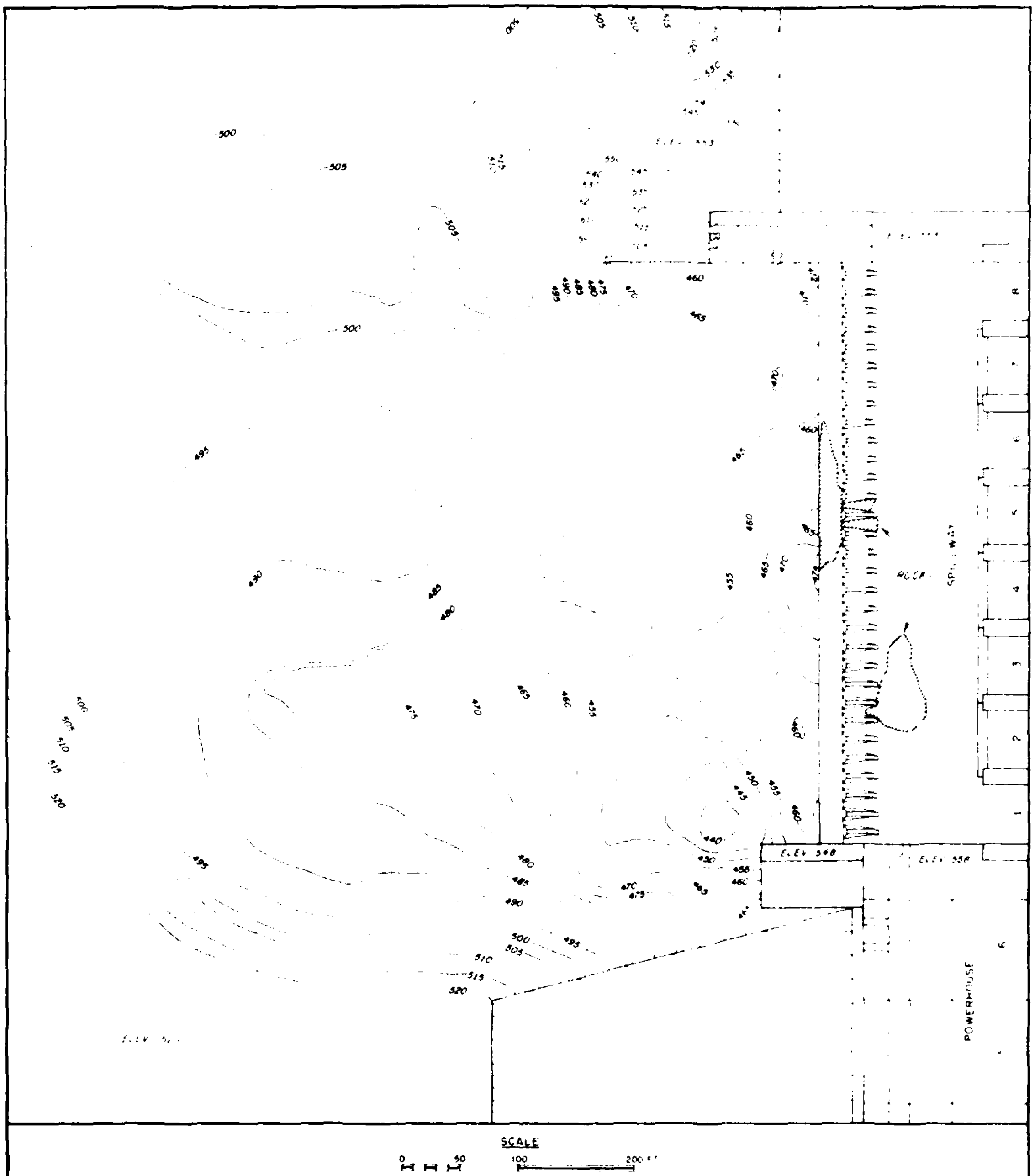
OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 3	66 900 CFS
SPILLWAY	
BAYS 1 AND 8	36 400 CFS
BAYS 2 TO 7	96 700 CFS
POOL ELEVATION	638 0
TAILWATER ELEVATION	542 8
TEST DURATION	21 HOURS

CHANNEL TOPOGRAPHY

RIVER DISCHARGE 200 000 CFS

PLATE 6

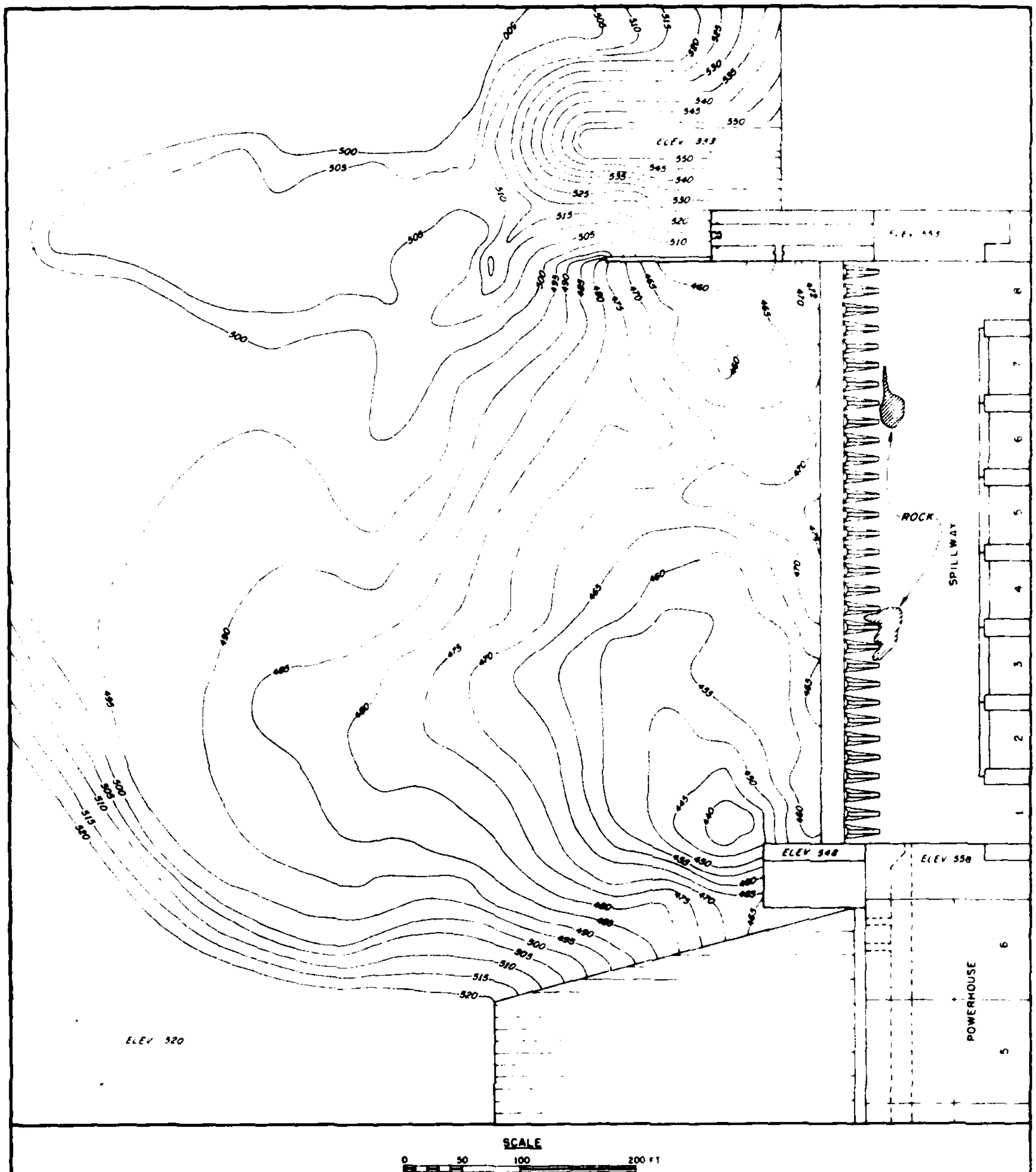


OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 3	66 000 CFS
SPILLWAY	
BAYS 1 TO 8	184 000 CFS
POOL ELEVATION	638.0
TAILWATER ELEVATION	544.0
TEST DURATION	42 HOURS

CHANNEL TOPOGRAPHY

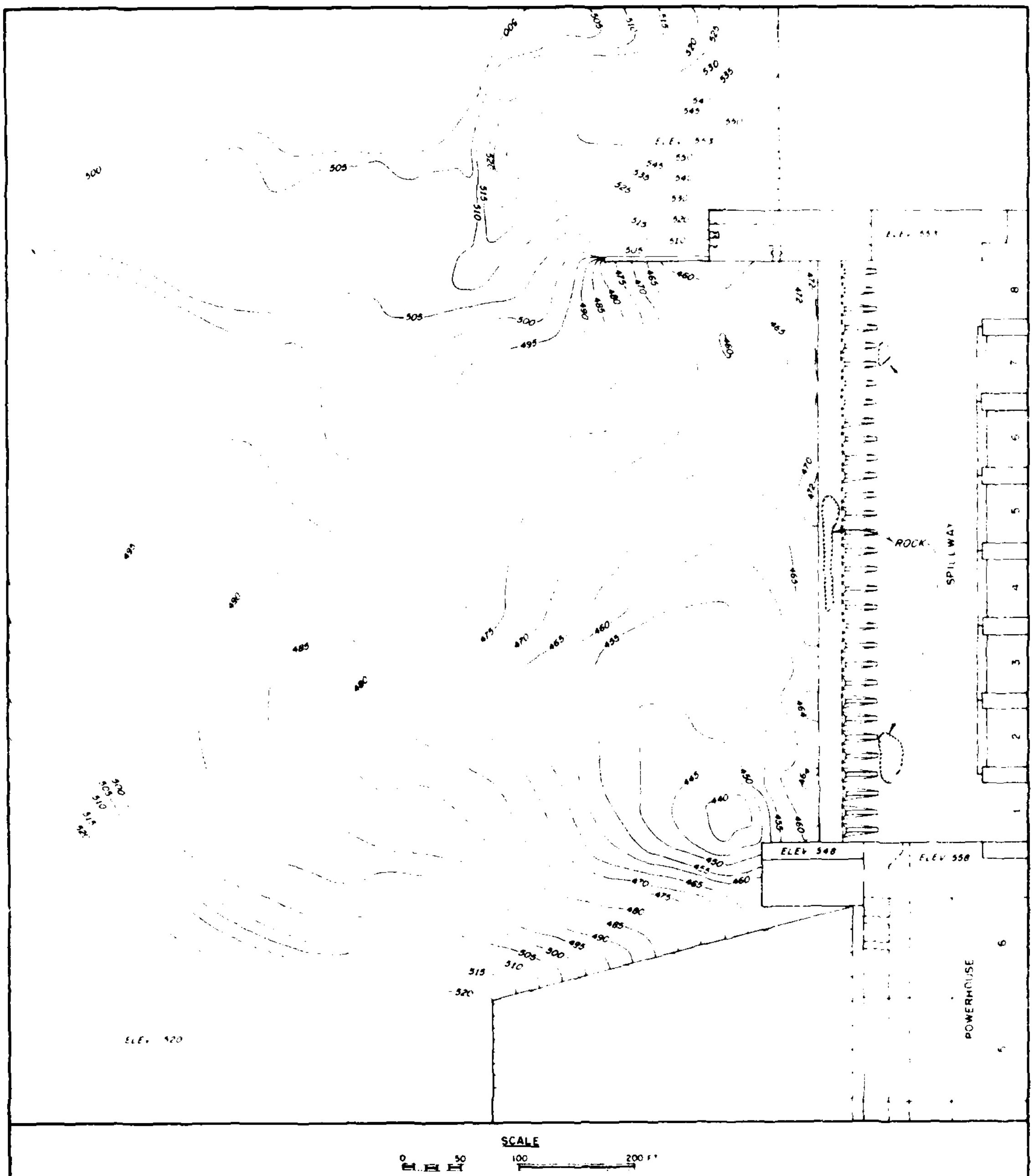
RIVER DISCHARGE 250 000 CFS



OPERATING CONDITIONS	
POWERHOUSE UNITS 1 TO 3	66 000 CFS
SPILLWAY BAYS 1 TO 8	214 000 CFS
POOL ELEVATION	638.0
TAILWATER ELEVATION	544.7
TEST DURATION	71 HOURS

CHANNEL TOPOGRAPHY

RIVER DISCHARGE 280 000 CFS



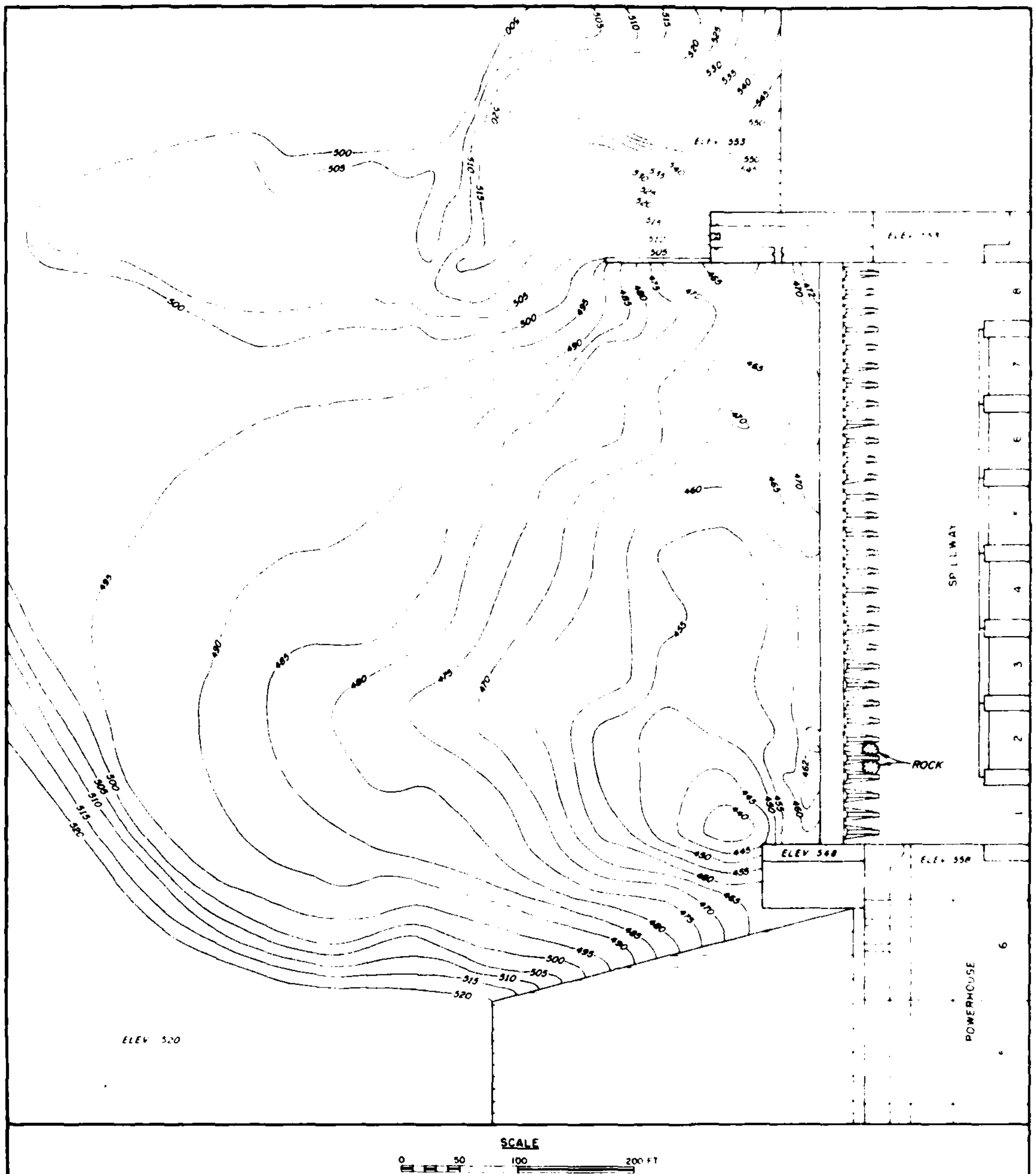
OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 3	66 000 CFS
SPILLWAY	
BAYS 1 TO 8	234 000 CFS
POOL ELEVATION	638 0
TAILWATER ELEVATION	545 2
TEST DURATION	63 HOURS

CHANNEL TOPOGRAPHY

RIVER DISCHARGE 300 000 CFS

PLATE 9

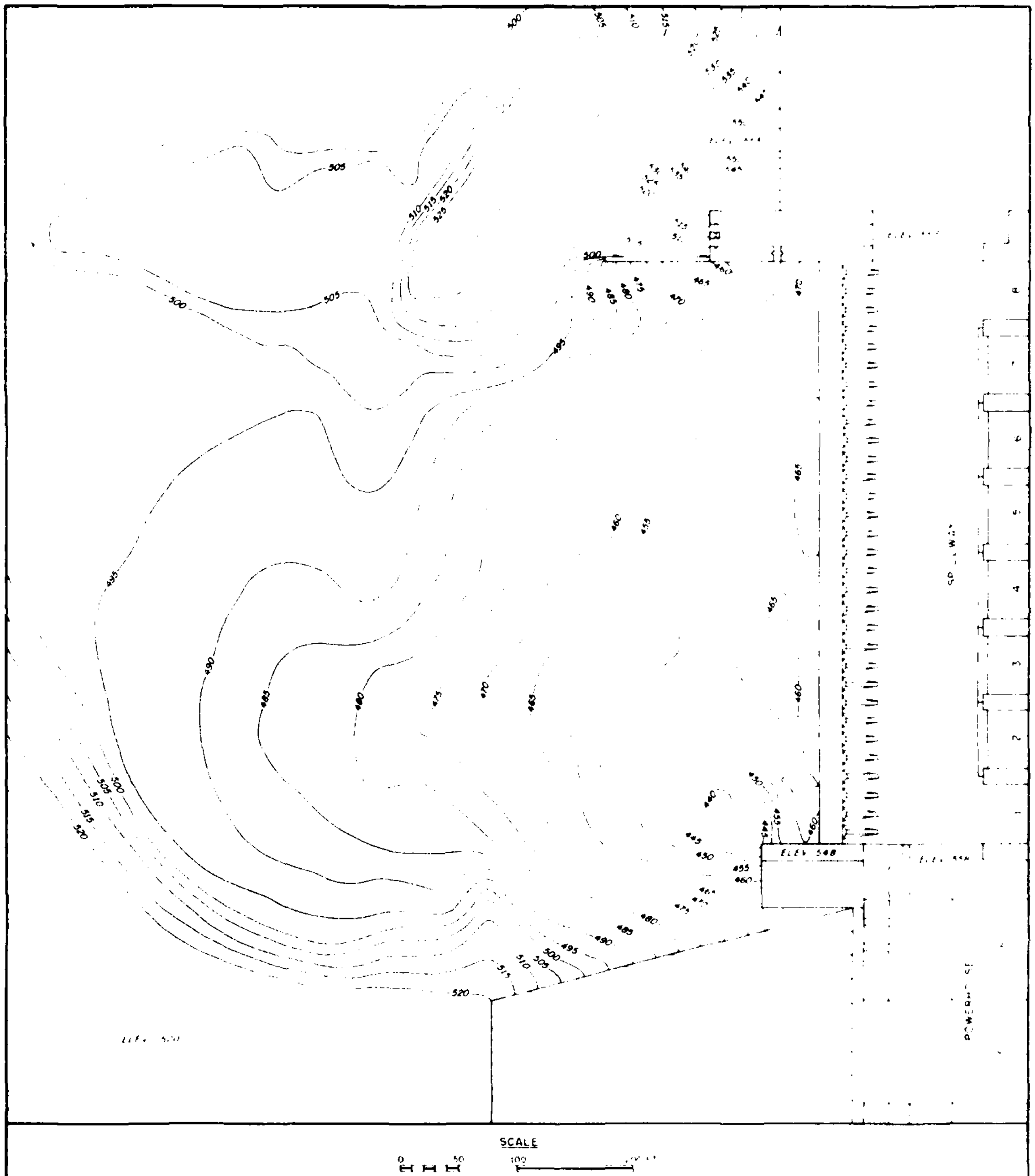


OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 3	66 000 CFS
SPILLWAY	
BAYS 1 TO 8	284 000 CFS
POOL ELEVATION	638 0
TAILWATER ELEVATION	546 5
TEST DURATION	49 HOURS

CHANNEL TOPOGRAPHY

RIVER DISCHARGE 350 000 CFS

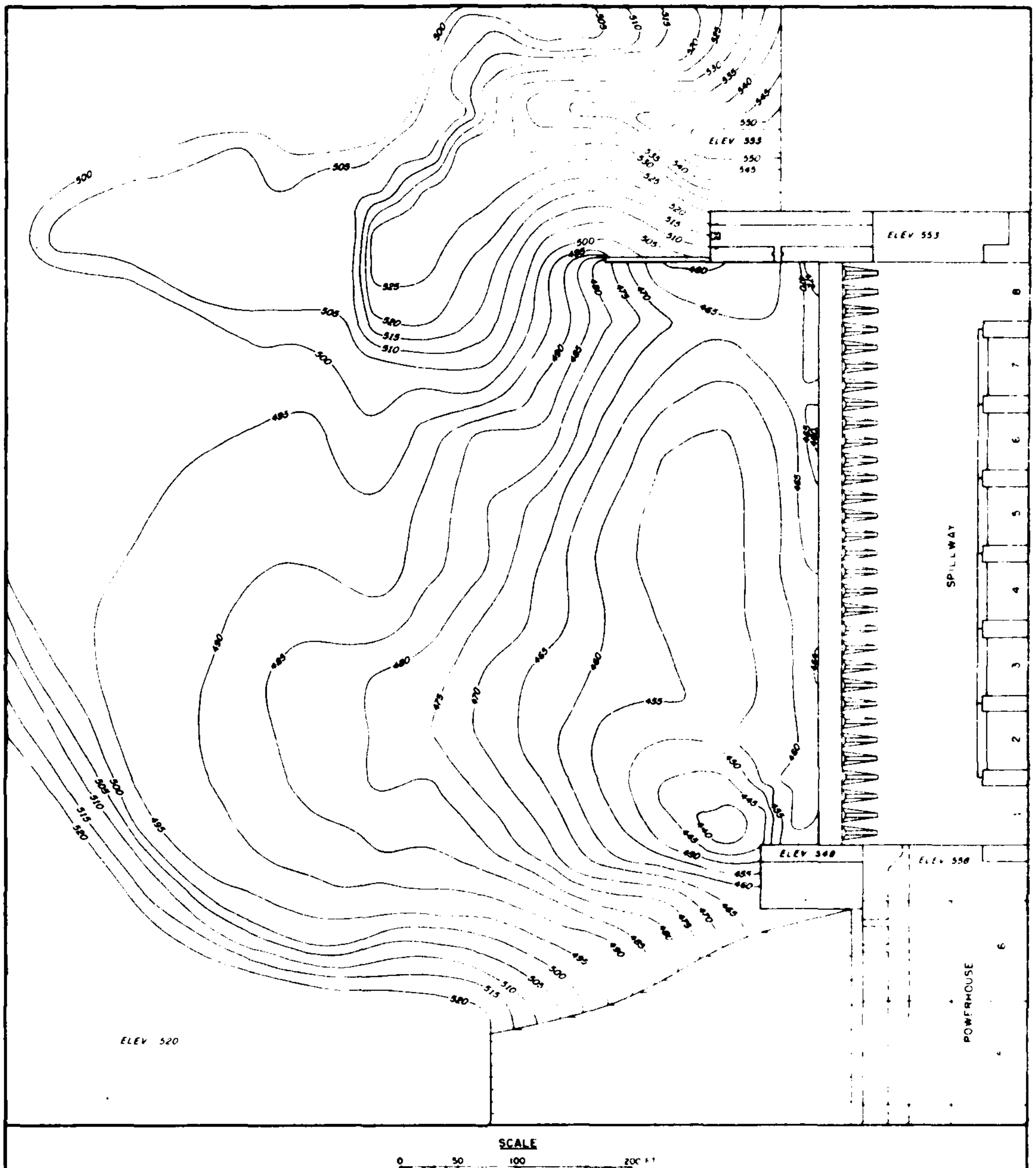


OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 3	66 000 CFS
SPILLWAY	
BAYS 1 TO 8	334 000 CFS
POOL ELEVATION	638.0
TAILWATER ELEVATION	547.8
TEST DURATION	63 HOURS

CHANNEL TOPOGRAPHY

RIVER DISCHARGE 400 000 CFS

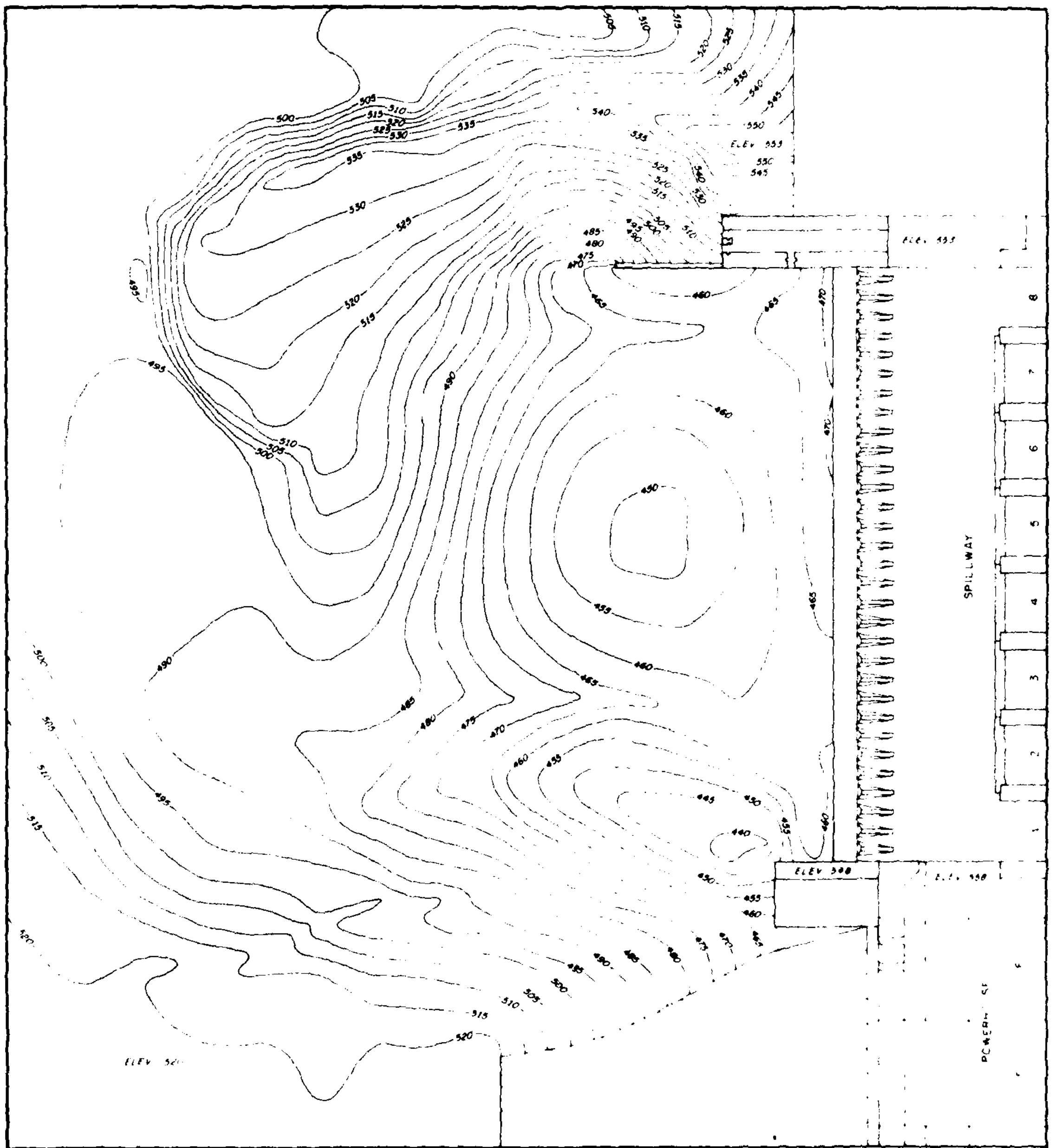


OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 3	66 000 CFS
SPILLWAY	
BAYS 1 TO 8	354 000 CFS
POOL ELEVATION	638.0
TAILWATER ELEVATION	548.3
TEST DURATION	42 HOURS

CHANNEL TOPOGRAPHY

RIVER DISCHARGE 420 000 CFS



SCALE

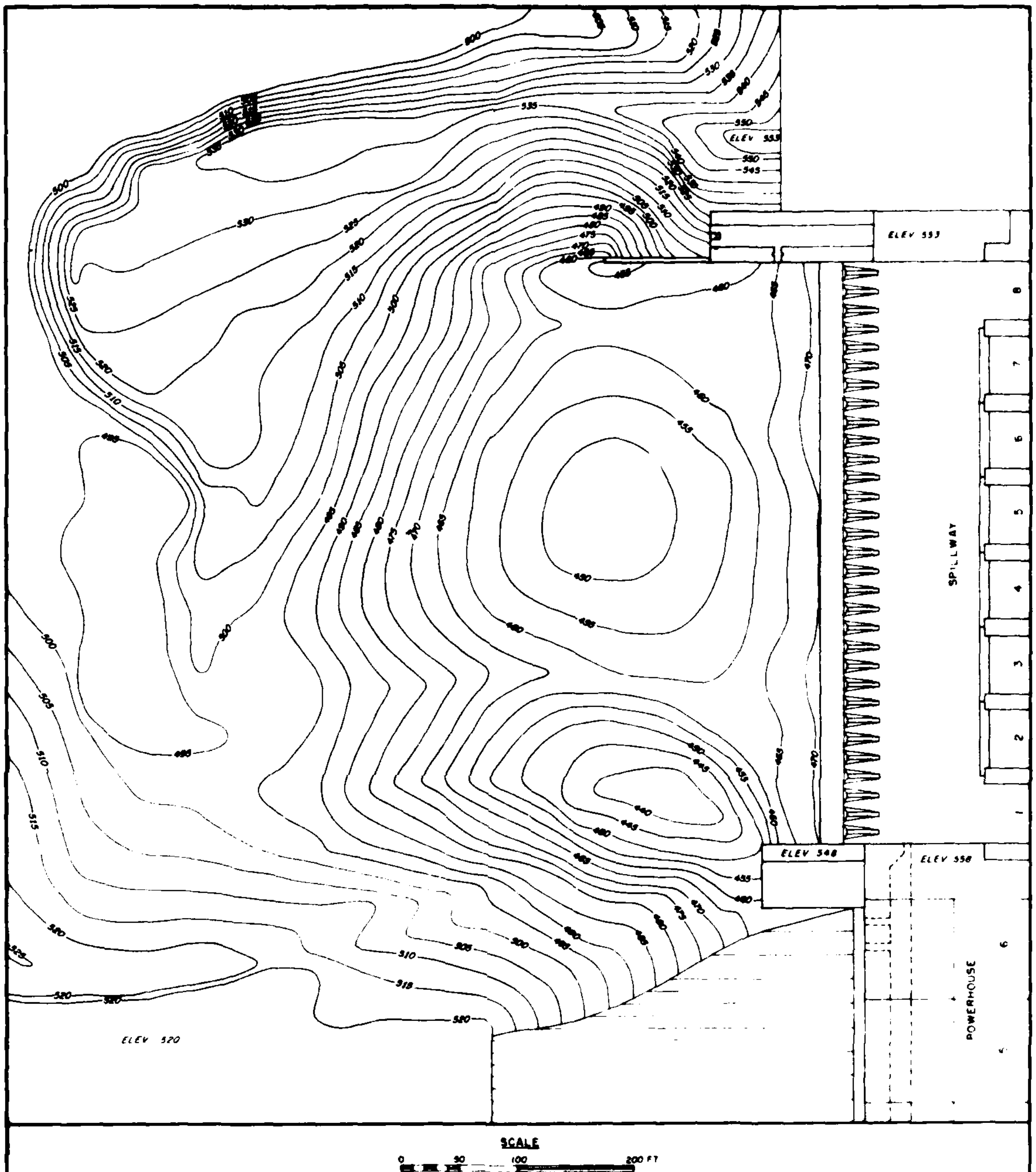
0 50 100 200 FT

OPERATING CONDITIONS

POWERHOUSE UNITS	CLOSED
SPILLWAY	
BAYS 1 TO 8	475 000 CFS
POOL ELEVATION	638.0
TAILWATER ELEVATION	549.4
TEST DURATION	56 HOURS

CHANNEL TOPOGRAPHY

RIVER DISCHARGE 475 000 CFS



OPERATING CONDITIONS

POWERHOUSE UNITS	CLOSED
SPILLWAY	
BAYS 1 TO 8	530 000 CFS
POOL ELEVATION	638.0
TAILWATER ELEVATION	551.0
TEST DURATION	71 HOURS

CHANNEL TOPOGRAPHY

RIVER DISCHARGE 530 000 CFS

PLATE 14

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